

# Corrosion

PUBLIC LIBRARY

AUG 1 1959

DETROIT

## IN THIS ISSUE:

**Notch Sensitivity Effects in Stress Corrosion  
and Hydrogen Embrittlement Tests on  
High Strength Steels . . . . . 17**

**Zinc in Marine Environments . . . . . 27**

**Internal Cathodic Protection of  
Large Pipes Carrying Sea Water . . . . . 35**

**Anchor Pattern Profile and Its Effect  
on Paint Performance . . . . . 46**

**Corrosion of Type 310 Stainless Steel  
by Synthetic Fuel Oil Ash . . . . . 61**

### NACE REGIONAL CONFERENCE PROGRAMS

Northeast Region . . . . . 72

Southeast Region . . . . . 87

Western Region . . . . . 88

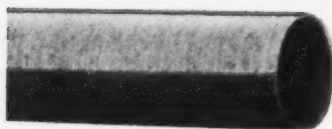
**Filming Amines Control Corrosion in  
Utility Plant Condensate System . . . . . 99**

**Recent Developments in Applying  
Polyvinylchloride Plastics . . . . . 107**

**Nickel Alloy Lining Cuts Costs  
in a Refinery Isomerization Unit . . . . . 109**



Complete Contents on Pages 2 and 3



**STRONG** as steel pipe



*...at one-eighth the weight!*



Circumferential Tensile Strength... 80,000 psi



**BONDSTRAND<sup>®</sup>**

*the revolutionary fiber glass  
reinforced epoxy pipe  
for corrosive service*

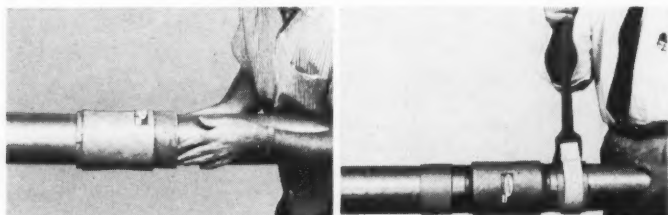


114

Here's a pipe that holds up indefinitely under the corrosive action of many salt, acid and alkaline solutions... that can't contaminate or flavor the piped material... that is rigid enough to resist sag, cold flow or deformation — flexible enough to follow normal ditch contours... that remains smooth and unlogged throughout its entire service life... that won't leak, even near its burst pressure.



Easy to install, with choice of locking wedge or threaded fittings.



Simple instructions with each shipment insure a perfect joint on the first try.



Dept. GH • 4809 Firestone Boulevard • South Gate, California

921 Pitner Avenue  
Evanston, Illinois

360 Carnegie Avenue  
Kenilworth, New Jersey

2404 Dennis Street  
Jacksonville, Florida

6530 Supply Row  
Houston, Texas

*A Subsidiary of American Pipe & Construction Company*

#### IN THE CHEMICAL INDUSTRY...

This means that you can use BONDSTRAND to transport corrosive solutions, waste water, sewage, oils, foods, beverages and many other troublesome fluids. It's also ideal for ducting, conduit or handrails where corrosive atmospheres, condensation, spillage or immersion cause troubles with ordinary pipe.





# CORBAN

*17 varieties  
for corrosion control;  
one quality—best!*

Corban® is the name given to Dowell's family group of corrosion inhibitors. They were developed to meet *your* problems. And there is a whole family of them, because corrosive well conditions vary so much.

First, Corban is offered in three forms: "ready-to-use" liquid, concentrated liquid and sticks. Then, Corban comes in more than a dozen formulas, each one designed for sweet crude, sour crude or gas condensate wells.

Corban can be applied by three methods: simple fluid-introduction down the annulus; stick-injection through lubricators or pressure locks; and the "squeeze" method of pumping liquid Corban back into the producing formation—proved for corrosion control over extended periods of time.

A variety of forms and formulas—to meet and control any corrosion problem on any well—is yours when you specify Corban. And, despite this variety, Corban is consistent in *quality*. Ask for an engineered corrosion study and recommendation from any of the 165 Dowell service points and offices. Dowell serves the oil industry in the United States, Canada, Venezuela and Argentina. Dowell, Tulsa 1, Oklahoma.

**Products for the oil industry**

DIVISION OF THE DOW CHEMICAL COMPANY

**DOWELL**

# Corrosion

Published monthly as its official journal, by the National Association of Corrosion Engineers, Inc., at Houston, Texas, U.S.A., as a permanent record of progress in corrosion control. Second class postage paid at Houston, Texas.

Vol. 15

August, 1959

No. 8

## EDITORIAL STAFF

IVY M. PARKER—Editor  
JAMES T. LONGINO  
Technical Editor  
DALE MILLER  
Editorial Assistant

## EDITORIAL REVIEW COMMITTEE

FRED M. REINHART, Chairman, National Bureau of Standards, Washington 25, D.C.

Mark F. Adams	T. L. Hoffman
A. L. Alexander	Harry J. Keeling
Philip M. Aziz	Frank E. Kulman
Joseph Bigos	Hugh L. Logan
W. W. Binger	Dwight G. Moore
W. B. Brooks	Charles C. Nathan
I. C. Dietze	J. W. Nee
A. C. Elm	V. B. Pike
Otto H. Fenner	Jane H. Rigo
N. D. Greene	A. H. Roebuck
John J. Halbig	D. H. Thompson
B. C. Haworth	L. E. Trishman
R. M. Wainwright	

## CORRESPONDENTS

H. Howard Bennett—Petroleum Refining  
K. G. Compton—Telephone, Telegraph and Radio  
S. W. Shepard—Non-Metals  
Leonard C. Rowe—Transportation Industry  
V. V. Kendall—Fresh and Salt Water  
T. F. Degnan—Chemical Industry  
Gordon B. Smith—Non-Ferrous Metals  
Norman D. Groves—Pulp, Paper, Mining and Food  
V. M. Kallhaug—Petroleum Production and Pipe Lines  
C. P. Larrabee—Ferrous Metals  
Herbert W. Kireck—Power  
Thomas J. Summerson—Light Metals

## BUSINESS STAFF

NORMAN E. HAMNER  
Managing Editor and Advertising Manager  
T. J. HULL  
(Executive Secretary NACE) Business Manager

Address all communications to:  
1061 M & M BUILDING  
Houston 2, Texas

## SUBSCRIPTION RATES (Post Paid)

Non-Members of NACE, 12 issues.....\$11.00  
Non-Members of NACE  
Single copies, 1957 to date..... 2.00  
NACE Members, Single Copies,  
1957 to date..... 1.00  
All Issues 1945-56 Inclusive, Per Copy..... 2.00  
Libraries of Educational Institutions  
and Public Libraries in the United  
States and Canada, 12 issues..... 4.00  
NACE Members Receive CORROSION as a Part  
of Their Membership at No Extra Charge.  
Foreign remittances should be by international  
postal or express money order or bank draft  
negotiable in the U. S. for an equivalent amount  
in U. S. funds. Entered as second class matter  
October 31, 1946, at the Post Office at Houston,  
Texas, under the act of March 3, 1879.

CORROSION is Indexed Regularly by Engineering Index and Applied Science and Technology Index.

# CONTENTS

## TECHNICAL SECTION

	Page
Corrosion of Aluminum Alloy in Glycol-Water Cooling Systems By N. S. Dempster.....	13
Notch Sensitivity Effects in Stress Corrosion And Hydrogen Embrittlement Tests on High Strength Steels By B. F. Brown.....	17
Uses and Abuses of Aluminum in Wooden-Hulled, Aluminum-Frame Minesweepers By T. H. Rogers and W. K. Chinn.....	21
Zinc in Marine Environments By E. A. Anderson.....	27
Corrosion Problems Associated With Sour Gas Condensate Production By D. R. Fincher.....	31
Internal Cathodic Protection of Large Steel Pipes Carrying Sea water By John H. Morgan.....	35
Duct Anode Development and Experience in Protection of Underground Cables from Corrosion By J. E. Johnson.....	41
Anchor Pattern Profile and Its Effect on Paint Performance By Joseph Bigos.....	46
Probability as Related to Stress Corrosion Cracking of Copper Alloys By D. H. Thompson.....	51
Stress Corrosion Cracking of Oil Country Tubular Goods By R. L. McGlasson and W. D. Greathouse.....	55
Corrosion of Type 310 Stainless Steel by Synthetic Fuel Oil Ash By Hugh L. Logan.....	61

## Technical Topics to Be Indexed in December Issue

Technical Topics published in CORROSION will be included in the alphabetical subject index, accumulated contents and their authors listed in the alphabetical author index which will appear in the December issue.

Copyright 1959 by the National Association of Corrosion Engineers. Reproduction of the contents, either as a whole or in part, is forbidden unless specific permission has been obtained from the Publishers of CORROSION. Articles presented represent the opinions of their authors, and not necessarily those of the Editors of CORROSION, nor the Officers or Members of the National Association of Corrosion Engineers. Manuscripts to be considered for publication should be forwarded, together with illustrations, to the Editor of CORROSION, 1061 M & M Building, Houston 2, Texas.

# CONTENTS

## TECHNICAL COMMITTEE ACTIVITIES

	Page		Page
Eight Committees Give Reports		T-6R .....	65
at Chicago .....	65	T-6A .....	65
T-5B .....	65	T-3A .....	65
T-2A .....	65	3rd Committee Joins Southeast	
T-6F .....	65	Region's Coordinating Committee..	65
T-4E .....	65	Cathcart With Tank Lining.....	65
T-2B .....	65		

## NACE NEWS

	Page		Page
Wide Scope of Topics Features		Canadian Region News	
Fall Meetings.....	67	Edmonton Section .....	71
North Central Region News		National and Regional Meetings	
Cleveland Conference to Have		and Short Courses.....	91
30 Papers .....	67		
March '59 Corrosion Issues		NORTHEAST REGION CONFERENCE	
Wanted for Library Uses.....	67	35 Papers and 3 Plant Visits to	
		Be Featured in Program.....	72
South Central Region News		Schedule of Events.....	72
Denver Conference Final		Technical Program .....	72
Plans Are Set.....	68	Abstracts .....	76
North Texas Section.....	68	Authors of Papers.....	82
Alamo Section .....	68	Biographies .....	84
Greater Baton Rouge Area			
Section .....	68	SOUTHEAST REGION CONFERENCE	
Australian Essay Prize Awarded		10 Corrosion Papers Are	
to NACE Member.....	69	Scheduled for Technical Program..	87
Permian Basin Corrosion Tour		Abstracts .....	87
To Be Sept. 23-25.....	69	Biographies .....	87
Section Calendar .....	69		
Appalachian Short Course Has		WESTERN REGION CONFERENCE	
Record Attendance .....	69	General Corrosion Problems to	
		Be Covered in Program.....	88
Northeast Region News		Technical Program .....	88
Philadelphia Section .....	71	Abstracts .....	88
Baltimore-Washington Section.....	71	Authors .....	90
Genesee Valley Section.....	71	Biographies .....	90
Past Chairman Certificate			
Presented to Walter Burton.....	71		
Western Region News			
Portland Section .....	71		
Puget Sound Section.....	71		
Los Angeles Section.....	71		
Index to Corrosion Abstracts.....	111		
Index to Advertisers.....	128		

## TECHNICAL TOPICS

Filming Amines Control Corrosion in Utility Plant Condensate System	
By Edward E. Galloway.....	99
Offshore Platform Shows Corrosion Rate of Carbon Steel in Gulf of Mexico Exposure	
By Dean Patterson .....	103
Material Selection in Chemical Milling Process	
By W. C. Rockwell.....	105
Recent Developments in Applying Polyvinylchloride Plastisols	
By J. Watson Pedlow.....	107
Nickel Alloy Lining Cuts Costs in a Refinery Isomerization Unit	
By John F. De Lorenzo.....	109

## Technical Topics Scheduled For September Publication

- Methods of Installing Cathodic Protection Anodes for Offshore Structures, by Wayne A. Johnson and James T. Condry
- Case Histories of Differential Aeration Corrosion in Underground Telephone Cables, by David T. Jones
- Mechanisms and Some Theoretical Aspects of Stress Corrosion Cracking of Austenitic Stainless Steels, by W. B. Brooks
- Rapid Field Measurement of Sub-Surface Corrosion of Aluminum, by Hugh P. Godard

## GENERAL NEWS

	Page
Zinc Anode Research May Solve	
Crab Pot Corrosion.....	93
Annual Titanium Meeting to Be	
September 14-15 .....	93
NBS Ferrous Samples .....	93
Plastics Society to Meet.....	93
Packaging Conference .....	93
Building Council to Meet.....	93
Book News .....	93
New Periodicals .....	93
British Corrosion Association	
Formed .....	93
Acid Mine Water Problem to Be	
Discussed by SME.....	93
Indian Metal Institute to Hold	
Annual Meeting .....	93
Plastics Conference .....	93
New Diesel Designs Permit Use of	
Lower Grade Fuels.....	94
Thicker Chromium Gives More	
Corrosion Resistance .....	94
Water Purification Plant.....	94
Stadium to Be Heated.....	94
Paper Given at ASME.....	94
Radioisotope Study .....	94
Corrosion Research Report.....	94
New Products .....	95
Men in the News.....	96

## Technical Articles Approved For Early Publication

- Mechanisms by Which Non-Ferrous Metals Corrode in the Atmosphere, by P. M. Aziz and H. P. Godard
- From the Panel to the Plant, by D. A. Ballard and V. B. Volkening
- A Modern Approach to Planning a Maintenance Coating Program for Pulp and Paper, by M. W. Belue
- Effects of Foreign Metals on Corrosion of Titanium in Boiling 2N Hydrochloric Acid, by W. Roger Buck, III, Billy Slope and Henry Leidheiser, Jr.
- Roofing Maintenance in the Chemical Industry, by W. G. Craig and J. C. Lemmon
- Metal Deterioration in Atmospheres Containing Carbon-Monoxide and Hydrogen at Elevated Temperatures, by W. B. Hoyt and R. H. Caughey
- Corrosion Testing of the Zircalloys, by Stanley Kass
- A Simple Screening Test for Determination of Inhibitor Film Persistence, by John A. Know and Roy Stout
- Reactive Coatings, by J. Kronstein
- Corrosion Inhibitor Evaluation From Cathodic Polarization Measurements, by R. A. Legault and Norman Hackerman
- Effect of Silicon on High Temperature Oxidation, by J. F. Radavich





## with **CARBOMASTIC** *heavy duty epoxy-tar coatings*

Generally, with protective coatings, undercutting begins at a damaged surface and corrosion progresses beneath the coating film. This corrosive loss can be prevented by priming with Carbomastic #3—unique because it contains inhibiting pigments. In addition, it features good surface wetting and outstanding adhesion.

These tough coatings are economical, too . . . providing lasting protection for less than 1¢ per mil foot. Recommended Carbomastic applications are:

### **OUTDOOR MAINTENANCE**

An all epoxy-tar system, with excellent weathering characteristics and high resistance to water and brines. Use Carbomastic #3 and Carbomastic #5 (topcoat). Color: aluminum.

### **TANK LININGS AND HEAVY DUTY MAINTENANCE**

High resistance to hot water, brines, sour crudes (hydrogen sulfide), acids and alkalis. Use Carbomastic #3 and Carbomastic #2 (topcoat).

Where color topcoats are desired, Carbomastics may be coated over with Phenoline 305 or Carboline Epoxy 150.

**WRITE TODAY** for Technical Bulletin #803, containing complete information on Carbomastic coatings, including suggested applications, general characteristics and testing results.

### **OFFICES**

Atlanta • Boston • Chicago  
Denver • Detroit • Houston • Los Angeles • Mobile • New Orleans  
New York • Philadelphia  
Pittsburgh • San Francisco  
Tampa • Toronto • Tulsa



*Coatings with  
Experience*

32-A Hanley Industrial Ct., ST. LOUIS 17, MO.



# GRANT Oil Tool

*announces the acquisition of*

## COSASCO DIVISION

of Perfect Circle Corporation

and the Cosasco line of patented access fittings  
(the original "Scotch" nipple)  
for corrosion surveys and unitized wellheads.

Effective July 13, 1959, it becomes the Cosasco Division of Grant Oil Tool Company and will be headquartered in our main plant in Los Angeles. The same high manufacturing standards exhibited in the broad Grant line of down-hole and surface tools and MacClatchie equipment will assure the continued excellence of Cosasco products.



# GRANT

**OIL TOOL COMPANY**

*Main Office and Plant:*

2042 East Vernon Avenue, Los Angeles 58, California

Cable Address: Grantool

Bakersfield, Compton, Ventura, Willows, California • Liberal, Kansas • Harvey, Houma, Lafayette, Louisiana • Laurel, Mississippi •  
Farmington, Hobbs, New Mexico • New York, New York • Oklahoma City, Oklahoma • Houston, Odessa, Texas • Casper, Wyoming  
Pincher Creek, Edmonton, Canada

# NACE Corporate Members and Representatives

Administracion Nacional de Combustibles  
Alcohol y Portland,  
Ing. Esquivel Perez Prins  
Alabama Gas Corporation  
T. G. Humphreys, Jr.  
Allegheny Ludlum Steel Corp.  
William G. Renshaw

Allied Chemical Corp.,  
Plastics & Coal Chemicals Div.  
P. B. Mayfield

Allied Chemical Corp., General Chemical  
Div.  
W. H. Burton  
Allied Chemical Corp., Solvay Process Div.  
G. E. Best

Allied Chemical Corp., Nitrogen Division  
H. C. Wintzer  
Alloy Steel Products Co.  
R. M. Davis

Aluminum Laboratories, Ltd.  
H. P. Godard

Aluminum Company of America  
Ellis D. Verink, Jr.  
Anchona Products, Inc.  
Alfred Dauty

Amercoat Corp.  
C. G. Munger

American Brass Co., The  
John R. Freeman, Jr.  
American Mollerizing Corp.  
H. E. Linden

American Oil Company  
Walter S. Janssen  
American Smelting Refg. Co., Federated  
Metals Div.  
R. D. Taylor

American Telephone & Telegraph Co.  
A. F. Minor

American Tobacco Co., The  
A. R. Anderson

American Zinc, Lead & Smelting Co.  
Robert Ammon

Apex Smelting Co.  
A. J. Peterson

Aquastrol, Inc.  
M. C. Forbes

Arbman American Oil Co.  
William F. Gross

Arizona Public Service Co.  
Frank Buck

Arkansas Fuel Oil Corp.  
L. F. Babcock

Arkansas Louisiana Gas Co.  
W. A. Broome

Armco Steel Corp.  
Arba Thomas

Armour Chemical Division, Armour & Co.  
J. E. Maloney

Atchison, Topeka & Santa Fe Railway  
Co., The  
E. B. Fields

Atlantic Pipe Line Co. (Penna.) Product  
Pipe Line Dept.  
Robert H. Lynch

Atlantic Refining Co., Producing Div.,  
The  
V. E. Stepp

Atlantic Refg. Co., Refining Div., The  
J. K. Delchier

Atlas Mineral Products Co., The  
Joseph A. Snook

Atlas Powder Company, Aquaness  
Department  
Fritz E. Fuchs

Babcock & Wilcox Co., The  
F. Eberle

Baltimore Gas & Electric Co.  
T. J. Dwyer

Baltimore & Ohio RR Co., The  
R. W. Seniff

Barnes & Delaney  
Pipe-Coating  
William R. Houck

Barnup and Sims, Inc.  
James H. Graham

Bataafsche Petroleum Mij., N. V. de  
H. A. van Offeren

Bechtel Corporation  
G. B. Grable

Bell Telephone Lab.  
Vernon B. Pike

Bessemer & Lake Erie Railroad Co.  
R. D. Lake

Bethlehem Steel Co.  
Seymour Charles Frye

Betz Laboratories, Inc.  
W. A. Tanzola

Bird-Archler Co., The  
Charles W. Bird

Blaw Knox Co., Chemical Plants Div.  
John Kull

Brace-Kracy Co., Inc.  
Wayne E. Broyles

Bridgeport Brass Co.  
R. V. Hall

Briggs Bituminous Composition Co.  
J. D. Farber

Briner Paint Mfg. Co., Inc.  
Felix Kellnake

British American Oil Co., Ltd.  
L. P. Blaser

BP (North America) Limited  
T. E. Pitkethly

Byers Co., A. M.  
R. J. Brimont

California Research Corporation  
F. W. Schremp

Cameron Iron Works, Inc.  
Rudy Zorn

Canadian Protective Coating Ltd.  
F. W. Heves

Canadian Vickers Limited  
P. W. Gooch

Canadian Western Natural Gas Co., Ltd.  
J. A. Snyder

Catholic Protection Service  
E. P. Doremus

Celcolite Co., Inc., The  
R. E. McMahon

Celanese Corp. of America  
J. A. Manning

Central Power & Light Co.  
William M. Mayer

Chain Belt Co. of Milwaukee  
Edmont R. Helmer

Champion Paper & Fibre Co., The  
Peter A. Klmen

Champion Oil & Refining Co.  
K. C. Cribley

Chanslor-Western Oil & Dev. Co., Chans-  
lor-Canfield Midway Div.  
John L. Stephens

Chesapeake and Ohio Railway Company,  
The, C. M. Angel

Chicago Bridge & Iron Co.  
I. E. Boberg

Chicoma Gas & Electric Co., The  
Milton J. Pfeiffer

Cit-Con Oil Corp.  
Robert L. Hale, Jr.

Cities Service Gas Co.  
Clint D. Rogers

Cities Service Pipe Line Co.  
Harry Nelson

Cities Service Refining Corp.  
L. D. Mann

Clementina, Ltd.  
K. F. Keefe

Clemtex, Ltd.  
Frank E. Wilson

Coast Paint & Lacquer Co., Inc.  
R. M. Johnson

Colorado Interstate Gas Co.  
Preston Parks

Columbia Gas System Service Corp.  
J. E. Overbeck

Columbia-Southern Chemical Corp.  
G. Helmenmann

Columbus & Southern Ohio Electric Co.  
N. R. Patton

Commercial Solvents Corporation  
Richard S. Ealy

Commonwealth Associates Inc.  
W. E. Bunting

Commonwealth Edison Co.  
Earle Wild

Consolidated Edison Co. of New York,  
Inc.  
L. B. Donovan

Consolidated Mining & Smelting Co. of  
Canada, Ltd.  
J. R. Wellington

Consumers Power Co.  
J. B. Simpson

Continental-Enasco Co.  
Albert S. Holbert

Continental Pipe Line Co.  
L. E. Maddux

Cook Paint & Varnish Co.  
Decker Freeman

Copper Alloy Corp.  
Herbert J. Cooper

Corn Prod. Co.  
Technical Div.  
R. E. Pierson

Corrosion Rectifying Co.  
Wayne A. Johnson

Cosden Petroleum Corp.  
R. W. Thompson

Crane Co.  
Chester Anderson

Cresle Petroleum Corp.  
S. J. Mathis

Crown Central Petroleum Corp.  
A. J. Morris

Crutcher-Rolls-Cummings, Inc.  
Jack Scott

Syd E. Culbertson Co., Inc.  
William B. Schell

Dallas Power & Light Co.  
Robert D. Elliott

Dampney Co., The  
J. Dwight Bird

Day, S. D., Co.  
David W. Peake

The Dayton Power & Light Co.,  
Corrosion Control Dept.  
Paul C. Hoy

Dearborn Chemical Co.  
R. F. Carr, Jr.

Deberolise Co., The  
Robert L. Deberolise

Delhi-Taylor Oil Corp.  
Walter E. Anderson

De Vilbiss Co., The  
D. J. Feeps

Diamond Alkali Company  
S. W. McIlrath

Douglas Aircraft Co., Inc.  
F. T. Wood, Jr.

Dow Chemical Co., The  
H. A. Humble

Dowell  
Guy F. Williams

E. I. du Pont de Nemours & Co., Inc.  
J. A. Collins

Duriron Co., The  
W. A. Luce

Duval Sulphur & Potash Co.  
J. W. Borskey, Jr.

East Bay Municipal Utility District  
Lee E. Herzberg

Eastern States Petroleum & Chem. Corp.  
Jack Dalberg

Ebasco Services, Inc.  
H. W. Wahlquist

Electro Rust-Proofing Corp.  
Frank P. Macdonald

Elizabethtown Consolidated Gas Co.  
George H. Coon

El Paso Natural Gas Co.  
L. G. Walman

Eso Research & Engineering Co.,  
Design Div., M. S. Northup

Ethyl Corp.  
H. S. Butler

Fabri-Valve Co. of America  
J. L. Williams

Farbrol Co.  
Irvin Baker

Fibreboard Paper Products Corp.  
Pabco Indus., Insulations Div.  
L. S. Parker

Food Machinery & Chemical Corp.  
Central Engineering Labs.  
E. H. Brink

Frances Oil Co.  
Frances Olson

Freeport Sulphur Co.  
William J. Blanchard

Furane Plastics Inc.  
John Deimonte

F. W. Gartner Company  
F. W. Gartner, Jr.

General American Transportation Corp.  
Paul Tulmney

General Electric Co., Industrial Mate-  
rials Div., H. A. Cataldi

General Petroleum Corp.  
Ralph M. Willis

Gibbs & Hill, Inc.  
E. H. Anson

Good-All Electric Mfg. Co.  
Troy R. Stille

B. F. Goodrich Chemical Co.  
R. J. Collins

Graver Tank & Mfg. Co., Inc.  
Phillip E. Rose

Great Lakes Pipe Line Co.  
C. C. Keane

Great Northern Railway Co.  
G. V. Guerin

Gulf Oil Corp.  
Walter F. Rogers

Gulf Oil Corp., Mfg. Div.  
D. L. Burus

Gulf Research & Development Co.  
L. W. Vollmer

Gulf States Utilities Co.  
W. W. Eckles

Gunnels Co., W. D.  
Wm. H. Stemler

Hackensack Water Co.  
A. Damiano

Hagan Chemicals & Controls, Inc.  
Threshold Treatment Div.  
John P. Kleber

Halliburton Oil Well Cementing Co.  
Roy Stout

Harbison-Fischer Manufacturing Co.  
D. T. Harbison

Hercules Powder Co., Chemical Eng. Div.  
David J. Torrans

Hill, Hubbell & Company,  
Division of General Paint Corp.  
Milton M. Bowen

Holcombe Company, Inc., The  
Tom L. Holcombe

Holders Equipment Co.  
S. D. McMullen

Hooker Electrochemical Co.  
Walter A. Szymanski

Houston Contracting Co.  
R. P. Gregory

Houston Natural Gas Corp.  
W. C. Dahlman

Houston Pipe Line Co.  
H. D. Carmouche

Humble Oil & Refining Co.  
H. D. Wilde

Humble Pipe Line Co.  
A. E. Pecore

Hydro-Electric Power Commission of  
Ontario, The  
D. G. Watt

Imperial Oil, Ltd., Pipe Line Division  
B. H. Mackenzie

Imperial Oil, Ltd., Prod. Dept.,  
Western Div.  
J. W. Young

Imperial Pipe Line Co., Ltd., The  
E. W. Christian

Inland Steel Co., Indiana Harbor Work  
R. L. Harbaugh

International Harvester Co.  
Earl F. Moorman

International Nickel Co., Inc., The  
W. Z. Friend

International Nickel Co. of Canada,  
Ltd., The  
R. J. Law

International Paint Co., Inc.  
Albert R. Smiles

International Rectifier Corp.  
F. W. Parrish

Interprovincial Pipe Line Co.  
F. J. Stubbs

Iowa Public Service Co.  
Wm. J. Dougherty

I. A. R. M., H. O. Operations  
A. K. J. van Schravendijk

Jersey Production Research Co.  
S. P. Ewing

Johns-Manville Corp.  
M. W. Gregory

Jones-Blair Paint Co.  
L. R. Kyrias

Jones & Laughlin Steel Corp.  
H. T. Clark

Kansas-Nbraska Natural Gas Co., Inc.  
Leonard C. Hill

K. W. Kellogg Co., The  
W. B. Hoyt

Kendall Co., The, Polyken Sales  
Division, Howard D. Segool

Keystone Roofing Manufacturing Co.  
Stephen A. Feely

Keystone Shipping Co.  
S. F. Spencer

Koppers Co., Inc., Tar Prod. Div.  
W. F. Fair, Jr.

Kroy Plastic Pipe Co., Inc.  
Russell W. Johnson

Laclede Gas Co.  
Delmar Hasenritter

Lester Equip. Manuf. Co., Inc.  
Don P. Wilson

Lever Brothers Co.  
E. K. Holt

Lion Oil Co.  
J. B. Rogerson

Lone Star Gas Co.  
John M. Kinkle

Long Island Lighting Co.  
William Welch, Jr.

Louisiana Power & Light Co.  
W. T. Hess

Lubrizol Corp., The  
Willis G. Craig

Magnolia Petroleum Co.  
J. D. Humble

Magnolia Pipe Line Co.  
James H. Ashley

Mallinckrodt Chemical Works  
C. A. Coberly

F. H. Maloney Co.  
James H. McBrien

Manning, Maxwell & Moore, Inc.  
Robert F. Ehrman

Mayer-Kelly Company  
Thos. F. Kelly

Metal Goods Corp.  
Charles G. Gribble, Jr.

Metallizing Engineering Co.  
R. J. McWaters

Metropolitan Water District of So. Calif.  
R. B. Diemer

Michigan Consolidated Gas Co.  
Karl E. Schmidt

Mid-Continent Pipe Line Co.  
F. E. Freund, Jr.

Mid-Valley Pipeline Co.  
F. H. Deal

Midwestern Pipe Line Products Co.  
John R. Wilson

Minnesota Mining & Mfg. Co.  
W. C. O'Leary

Mississippi River Fuel Corp.  
G. B. Lowther

Mississippi Valley Gas Co.  
J. H. Lambdin

Monier-Lenoir Mfg. Co.  
Mrs. Penny H. Williams

Monsanto Chemical Co.  
F. L. Whitney, Jr.

Montana Power Co.  
Carl R. Davis

Morton Salt Company  
Horace W. H. Diamond

Mountain Fuel Supply Co.  
Harry R. Brough

Napco Corp.  
Joseph E. Rensch

Nalco Chemical Company  
J. W. Ryznar

(Continued on Page 8)

## Figuring tubing materials on a cost per year basis?

# NEW 4-D WROUGHT IRON costs less, lasts longer

The lower the cost per year, the more economical the investment. Especially so when the material lasts a long, long time. Take the cost comparisons below. Based on actual installations, users of wrought iron cold drawn tubing have been investing wisely for many years. Now, with new 4-D Wrought Iron available, your savings are even greater.

Note: New 4-D Wrought Iron was achieved by substantially increasing the deoxidation of the base metal, slightly increasing the phosphorous content and using a more siliceous iron silicate.

Result is *increased* corrosion-resistance, *improved* mechanical and physical properties.

INSTALLATION	COST PER FOOT PER YEAR	
	WROUGHT IRON	STEEL
Hotel, Brooklyn, New York Hot ammonia gas passing through interior of tubes, cooled by salt water circulating along outside of tubes.	\$ .03 (19 years)	\$ .24 (2 years)
Ice Company, Chicago, Illinois Carbon dioxide condenser service.	.03 (18 years)	.05 (10 years)
Film Corporation, Binghamton, New York Tubes used in cooling service.	.04 (15 years)	.06 (8 years)
Industrial Plant, New Bedford, Massachusetts Ammonia condenser with salt water in coolant.	.04 (12-14 years)	.48 (1 year)
Industrial Plant, Toronto, Canada Tube and shell type condenser used for cooling brine with ammonia.	.01 (50 years)	.07 (7 years)
Ice Company, Aiken, South Carolina Ammonia condensers with mild brine solution containing 76 ppm sodium chloride for cooling.	.03 (18 years)	.29 (2 years)
Ice Company, Rocky Mount, North Carolina Condensers with mild brine solution containing 75 ppm sodium chloride for cooling.	.07 (8 years)	.16 (3 years)
Industrial Plant, Wisconsin Vaporizers for production of butane and propane gas. Severe stresses created by wide temperature variances.	.28 (2 years)	.96 (6 months)
Oil Company, Long Island City, New York Cool, weak ammonia liquor cools hot, concentrated ammonia liquor coming from generator on the way to absorber.	.03 (20 years)	.07 (6-8 years)
Process Company, Detroit, Michigan Heat exchangers with ammoniated brine concentration of about 10% ammonia and salt almost to saturation point.	.08 (8 years)	.16 (3 years)
Gas Company, Brooklyn, New York Ammonia condenser with cooling medium of creek water contaminated by the refuse from several nearby industrial plants.	.05 (16 years)	.22 (3-5 years)
Alkali Company, Saltville, Virginia Heat exchanger carrying ammonia liquor that is subsequently cooled by surrounding water.	.05 (16 years)	.30 (6 mos.-3 years)
Industrial Plant, Chicago, Illinois Condenser tubes in absorption system. Ammonia inside the tubing is about 200°F. and water outside the tubes is about 40°F.	.09 (9-11 years)	.28 (3 years)
Electric Utility Company, Hunts Point, New York Gas cooler drawing water from East River in New York City.	.15 (8-9 years)	.45 (2-3 years)
Warehouse & Cold Storage Corp., Springfield, Massachusetts Ammonia condensers and direct expansion cooling coil.	.02 (30 years)	.04 (12 years)

"Cost per foot per year" figures are calculated from current prices of cold drawn seamless steel tubing (ASTM A-179) and cold drawn wrought iron tubing (ASTM A-382). Because of the many variables involved, costs for installation labor, maintenance and replacement are not included. If they were, wrought iron's low cost story would, of course, be even more impressive.

Details on any of the above installations furnished on request. Write for Wrought Iron Heat Exchanger and Condenser Tubing bulletin.



## BYERS 4-D WROUGHT IRON

TUBULAR AND FLAT ROLLED PRODUCTS

A. M. BYERS CO., CLARK BLDG., PITTSBURGH 22, PA.

**Corrosion costs you more than Wrought Iron**

# NACE Corporate Members and Representatives

National Lead Co.  
Roy Dahlstrom  
National Steel Corp.  
Res. & Dev. Dept.  
E. J. Smith  
National Supply Co., Tubular Div.  
Dr. Lawrence E. Trishman  
National Tank Co.  
Clarence O. Glasgow  
Nason Mfg. Co.  
Anil N. Shah  
New Jersey Zinc Co. of Pa., The  
Research Dept.  
E. A. Anderson  
New Orleans Public Service, Inc.  
Lionel J. Cucullu  
Nicolet Industries, Inc.  
Ladd L. Wilson  
Norfolk & Western Railway Co.  
C. L. Crockett  
Northern Illinois Gas Co.  
M. G. Markle  
Northwestern Utilities, Ltd.  
M. E. Stewart

Oakite Products, Inc.  
Robert F. Ayres  
Ohio Oil Co., The  
Ralph M. Slough  
Oil Well Supply Div.  
F. L. Current  
Oklahoma Natural Gas Co.  
P. E. Wallace  
Olin Gas Transmission Corp.  
O. C. Roddey  
Olin Mathieson Chemical Corp., Tech.  
Div., Metals  
John B. Seastone  
Omaha & Council Bluffs Electrolysis  
Committee  
R. A. Pesek  
Otis Engineering Corp.  
W. M. Kelly  
Owens-Corning Fiberglass Corp.  
William A. Stutta

Pacific Gas & Elec. Co.  
Roy O. Dean  
Pacific Lighting Gas Supply Co.  
N. K. Senatoroff  
Pacific Northwest Pipeline Corp.  
William C. Brady  
Page-Hersey Tubes, Ltd.  
John D. Brethaupt  
Pan American Petroleum Corp.  
Joseph B. Clark  
Panhandle-Eastern Pipe Line Co.  
M. K. Hager  
Parker Rust Proof Co.  
E. W. Richards  
Pennsalt Chemicals Corp.  
R. R. Pierce  
The Pennsylvania Railroad Co.  
M. A. Finney  
Peoples Gas Light & Coke Co., The  
J. L. Adkins  
Permian Enterprises, Inc.  
Thomas H. Duff  
Perrault Equipment Co.  
V. V. Malcolm  
Petrolite Corp.  
G. J. Samuelson  
Philadelphia Electric Co.  
E. S. Halfmann  
Philip Carey Manufacturing Co., The  
John F. MacKay  
Phillips Petroleum Co.  
Frederick A. Prange  
Pipe Line Service Corp.  
F. C. Yeazel  
Pipe Linings, Inc.  
Robert L. Hansen  
Pittsburgh Coke & Chemical Co.  
A. E. Gray  
Plantation Pipe Line Co.  
W. G. Horstman  
Plastic Applicators, Inc.  
H. M. Kellogg  
Plastic Engineering & Sales Corp.  
Sam D. Hollinger  
Plicoflex, Inc.  
B. E. Black  
Portland Pipe Line Corporation  
Carlton L. Goodwin

Premier Oil Refining Co. of Texas  
David D. Pickrell  
H. C. Price Co.  
R. P. White  
Procter & Gamble Co., Engr. Div., The  
George F. Lockeman  
Production Profits, Inc.  
H. L. Bilhartz  
Products Research Service, Inc.  
Philip B. Wogan  
Public Service Electric & Gas Co.  
Donald C. Luce  
Pure Transportation Co.  
D. C. Glass

Radio Receptor Company, Inc.  
Julian Loebenstein  
Raytherm Corporation  
F. Raymond Young  
Reilly Tar & Chemical Corp.  
J. H. Barnett, Jr.  
Remco Pipeline Equipment & Supplies  
Bo Bardsley  
Republic Steel Corp.  
Giles Locke  
Reynolds Metals Company  
Robert S. Dalrymple  
Cyrus Wm. Rice & Co.  
James K. Rice  
Richfield Oil Corp.  
D. F. Purdy  
Robinson, E. W. Supply Co.  
James E. Freeman  
Rochester Gas & Electric Corp.  
Edward J. Nelson  
Rockwell Mfg. Co., Meter & Valve Div.  
Jack W. Harris  
Rosson-Richards Co.  
S. L. Richards, Jr.  
Rust Proofing, Inc.  
Harold B. Newsom

S.T.E.C.T.A.  
Georges Poirier  
St. Joseph Lead Co.  
Dwight Marshall  
St. Louis Metallizing Co.  
Walter B. Meyer  
St. Louis-San Francisco Railway Co.  
M. A. Herzog  
Salt Lake Pipe Line Co.  
L. G. Haskell  
San Diego Gas & Electric Co.  
Donald P. Armbruster  
San Francisco Water Dept.  
James H. Turner  
Sargent & Lundy  
Ludwig Skog, Jr.  
IMPER—Ing. A. Schleroni & Figli  
Ing. Franco Schleroni  
Service Pipe Line Co.  
J. R. Polston  
Shamrock Oil & Gas Corp., The  
Dan F. Long  
Shell Chemical Corp.  
A. L. Petersen  
Shell Development Co.  
R. S. Treseder  
Shell Oil Co., Inc.  
W. A. Bonner  
Shell Pipe Line Corp.  
L. B. Nelson  
Shippers' Car Line Division ACF Industries  
Ernest H. Colby  
Signal Oil & Gas Co.  
E. O. Kartinen  
Sinclair Pipe Line Co.  
Glenn L. Ladd  
Sinclair Research Laboratories, Inc.  
F. M. Watkins  
Slime Industrial Painters  
Louis L. Silne  
A. O. Smith Corp.  
L. C. Wasson  
Socony Mobil Oil Co. Inc.,  
Central Pipe Lines Div.  
Gerald J. Paisley

Socony Mobil Oil Co. Inc.,  
Eastern P. L. Div.  
S. Kleinhekel  
Socony Paint Products Co.  
Edwin Saul, Jr.  
Sohio Petroleum Co.  
S. B. Lisle  
Sohio Pipe Line Co.  
A. A. Dorff  
South African Bureau of Standards  
Clemens Crispus Van Der Merwe  
Southeastern Pipe Line Co.  
R. P. Hamilton  
Southern Bell Telephone & Telegraph Co.  
T. J. Cook  
Southern California Gas Co.  
J. S. Dorsey  
Southern Counties Gas Co. of Calif.  
W. C. Mosteller  
Southern Minerals Corp.  
F. P. Peterson, Jr.  
Southern Natural Gas Company  
O. W. Clark  
Southern Pacific Company  
W. M. Jackle  
Southern Pacific Pipe Lines, Inc.  
R. R. McDaniel  
Southern Union Gas Co.  
N. P. Chesnut  
Southwest Natural Gas Co.  
F. A. Merfeld  
Southwestern Electric Power Co.  
J. E. Moody  
Southwestern Public Service Co.  
H. O. Hodson  
Spencer Chemical Company  
Ralph D. Miller  
Standard Oil Co. of Calif.  
D. Roger Loper  
Standard Oil Co. (Ind.),  
Pro. Pipe Line Dept.  
V. M. Kalhaug  
Standard Pipe Protection, Inc.  
Hugh W. Baird  
Standard Railway Equipment Mfg. Co.  
J. S. Swann  
Stauffer Chemical Co.  
J. B. Ceccon  
D. E. Stearns Co., The  
D. E. Stearns  
Steelcote Manufacturing Co.  
Douglas A. Nield  
Sun Oil Co. Production Laboratory  
William F. Oxford  
Sun Pipe Line Co.  
W. H. Stewart  
Sunray Oil Corp.  
R. H. Poetker  
Superior Iron Wks. & Sply. Co., Inc.  
V. J. Martzell  
Superior Oil Company, The  
William H. Edwards

Tennessee Gas Transmission Co.  
J. L. Parrish, Jr.  
Texaco-Cities Service Pipe Line Co.  
B. W. Nedbaek  
Texaco, Inc.  
W. S. Quimby  
Texas Eastern Transmission Corp.  
Pat H. Miller  
Texas Electric Service Co.  
C. W. Geue  
Texas Gas Transmission Corp.  
Fred D. Stull  
Texas Gulf Sulphur Co.  
C. O. Stephens  
Texas Pipe Line Co., The  
Paul T. Miller  
Texstream Corporation  
L. V. Musgrove  
Tex-Tube, Inc.  
R. W. Kearney  
Thornhill-Craver Co.  
C. R. Horn  
Tidewater Oil Co.  
A. M. Mouser

Tinker & Razor  
Leo H. Tinker  
Trans-Arabian Pipe Line Co.  
F. P. Nibley  
Transcontinental Gas Pipe Line Corp.  
S. J. Bellasai  
Trans Mountain Oil Pipe Line Co.  
C. D. Bailey  
Trans-Northern Pipe Line Co.  
L. R. Dickinson  
Tresco, Inc.  
D. L. Korn  
Triangle Conduit & Cable Co., Inc.  
Roger E. Marth  
Trunkline Gas Co.  
A. T. Surber, Jr.  
Truscon Labs Div.  
Devoe & Reynolds Co., Inc.  
R. E. Madison  
Tube-Kote, Inc.  
E. G. Holm  
Tube Turns Plastics, Inc.  
George H. Hunt  
Tuscarora Pipe Line Company, Ltd.  
John W. de Grott

Union Carbide Corp.  
George A. Sands  
Union Electric Co.  
George F. Gamble  
Union Gas Company of Canada, Ltd.  
Ralph E. Kuster  
Union Oil Co. of Calif., Research Center  
J. E. Sherborne  
Union Pacific Railroad Co.  
Lee S. Osborne  
Union Producing Co.  
E. L. Rawlins  
Union Tank Car Co.  
Daniel W. Havens  
United Gas Corp.  
C. L. Morgan  
United Gas Pipe Line Co.  
M. V. Cousins  
United States Pipe & Foundry Co.  
A. E. Schuh  
U. S. Steel Corp., National Tube Div.  
Raymond C. Bowden, Jr.  
United States Steel Corp., Applied  
Research Laboratory  
C. P. Larabee  
Universal Control Corp.  
Charles D. Peterson  
Universal Oil Products Co.  
Eugene M. Matson

Vapor Honing Co., Inc.  
Jack Eggleston  
Vapor Recovery Systems Co.  
Frank V. Long, Sr.  
Visco Products Co., Inc.  
D. M. Jacks

Western Kentucky Gas Co.  
J. L. Bugg  
Western Natural Gas Co.  
Paul C. Wright, Jr.  
Wheeling Steel Corporation  
Henry A. Stobbs  
T. D. Williamson, Inc.  
T. D. Williamson, Jr.  
Wisconsin Protective Coating Co.  
Francis J. Floederl  
Wolverine Tube Division of  
Calumet & Hecla, Inc.  
John M. Keyes  
Worthington Corp.  
W. M. Spear  
Wright Chemical Corp.  
Paul G. Bird  
Wyandotte Chem. Corp.  
L. W. Gieckman  
Youngstown Sheet & Tube Co., The  
Karl L. Fotters

## SCHEDULED FOR PUBLICATION IN SEPTEMBER CORROSION

Factors Influencing Corrosion, by G. V. Akimov

Corrosion Inhibitors for Carbon Tetrachloride-Water Vapor Atmospheres by K. W. Calkins and R. W. Hawley

Action of the  $XO-\frac{n-}{4}$  Inhibitor, by G. H. Cartledge

Corrosion Processes in Carbonated Beverage Cans, by E. L. Koehler, J. J. Daly, Jr., H. T. Francis and H. T. Johnson

Development in Controlling Cargo Tank Corrosion, by J. Franklin Koehler

Four-Tower Water Treatment Test Facility, by R. G. Murray and M. E. Tester

Chloride Stress Corrosion Inhibitor Program, by J. H. Phillips and W. J. Singley

Design and Materials for Reduced Pump Corrosion, by J. E. Piccardo

Use of Magnesium for Cathodic Protection of Pump Lines in High Resistivity soil, by A. W. Peabody

Principles and Criteria for Cathodic Protection of Steel in Sea Water, by M. H. Peterson



for cathodic protection...

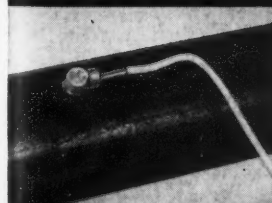
**BURNDY**  
**thermOweld®**

**FIRES EVERY TIME!**

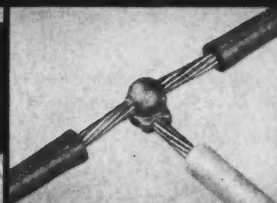


**THE POWDER MAKES THE DIFFERENCE!**

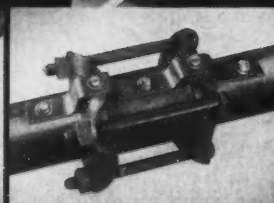
THERMOWELD's cohesive starting powder can't mix with the welding charge. This assures full-strength ignition that fires the welding charge every time. Just pour the welding charge from the moisture-tight cartridge into the Thermo-welder and tap to release special starting powder. Ignite for perfect, permanent electrical weld connections—anode and header leads, jumper bonds, and other cathodic protection connections.



**Anode Leads**  
Sounder, surer welds



**Header Leads**  
Higher conductivity connections



**Jumper Bonds**  
Easier strap or cable bonds

For complete details on softer slag, sure-fire THERMOWELD connections for cathodic protection, call your Burndy representative or write: **BURNDY**, Norwalk, Connect.

**BURNDY**

Norwalk, Connect.

In Europe: Antwerp, Belgium

Toronto, Canada

59-10

REG. U.S. PAT. OFF.  
**SCOTCHRAP**

BRAND  
PIPE PROTECTION

**Tapes are  
TOUGHER!**

**Proved by  
200-hour  
torture test!**



Each of the five lengths of pipe shown was covered with a different protective coating—both tapes and mill coatings. They were then fastened in a barrel containing abrasive tumbling chips and continually tumbled for 200 hours. This unretouched photo shows the results: only the "SCOTCHRAP" Pipe Protection Tape, far right, survived intact!

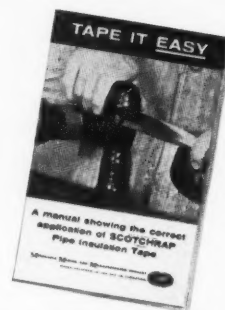
This controlled test was designed to measure the resistances of various coatings to backfilling and soil stresses. It clearly demonstrates the superior abrasion and puncture resistance and excellent bond strength you get *only* with "SCOTCHRAP"—the toughest polyvinyl chloride plastic tape. These properties are so superior that with normal care, no protective overwrap is needed. Add the excellent electric properties, and you have the reasons why we believe "SCOTCHRAP" is the best total coating buy you can make.

**FOR MAXIMUM ABRASION RESISTANCE . . .  
EXCELLENT PUNCTURE RESISTANCE . . .  
MAXIMUM RESISTANCE TO SOIL STRESS . . .  
PLUS EXCELLENT ELECTRICAL PROPERTIES  
SPECIFY**

REG. U.S. PAT. OFF.  
**SCOTCHRAP** Pipe Protection Products  
BRAND

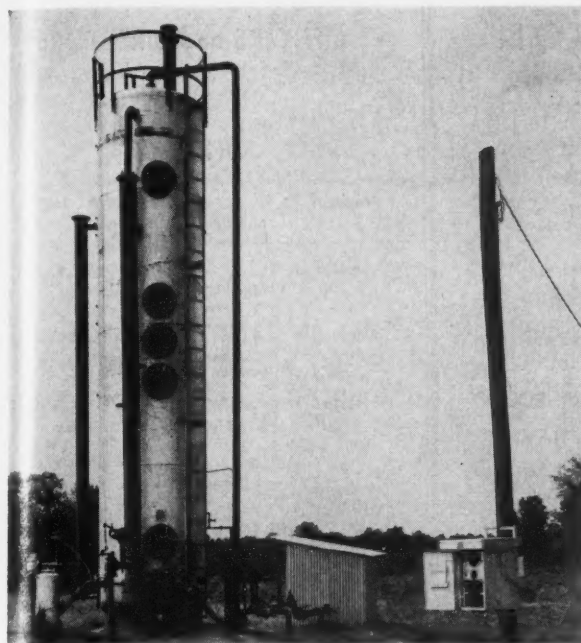
The term "SCOTCHRAP" is a registered trademark of Minnesota Mining and Mfg. Co., St. Paul 6, Minn. Export Sales Office: 99 Park Avenue, New York 16, N.Y. In Canada: P.O. Box 757, London, Ontario.

**MINNESOTA MINING AND MANUFACTURING COMPANY**  
... WHERE RESEARCH IS THE KEY TO TOMORROW



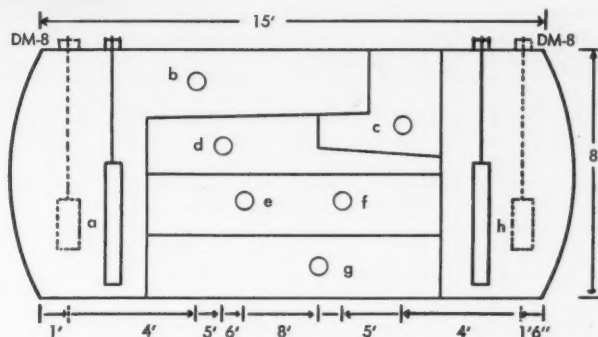
**SEND FOR FREE MANUAL!**

New "Tape it Easy" booklet gives application methods, useful specifications, for "SCOTCHRAP" Pipe Protection Products. Write 3M Co., St. Paul 6, Minn., Dept. EAM-89.



*Have You...*

## **Oil Field Vessel Internal Corrosion Problems?**



This drawing depicts anode placement for both magnesium and graphite.

ANODE	AREA	CURRENT
a	175 sq. ft.	1.75 Amps
b	100 sq. ft.	1.00 Amps
c	78 sq. ft.	.78 Amps
d	194 sq. ft.	1.94 Amps
e	97 sq. ft.	.97 Amps
f	97 sq. ft.	.97 Amps
g	154 sq. ft.	1.54 Amps
h	165 sq. ft.	1.65 Amps
<b>Total</b>		<b>10.60 Amps</b>

If you do have oil field vessel internal corrosion problems . . . Cathodic Protection Service has available for you a recommended engineered cathodic protection system.

This system can be obtained either directly from us or your local tank company. You can

obtain recommended engineered design protection systems using impressed or sacrificial anodes.

Phone, wire or write our home office or any of our branch offices listed below for additional information.

Cable Address — CATPROSERV

## **cathodic protection service**



P. O. Box 6387

CHICAGO  
122 S. Michigan Blvd., Rm. 964  
WEBster 9-2763

CORPUS CHRISTI  
1620 South Brownlee  
TULip 3-7264

Houston 6, Texas

DENVER  
(Golden) P. O. Box 291  
CRestview 9-2215

Jackson 2-5171

NEW ORLEANS — ODESSA  
1627 Felicity 5425 Andrews Hwy.  
JACKson 2-7316 EMerson 6-6731

TULSA  
4407 S. Peoria  
Riverside 2-7393





# NATIONAL ASSOCIATION of CORROSION ENGINEERS

Executive Offices: 1061 M & M Bldg., Houston 2, Texas

Telephone CApitol 4-6108

Executive Secretary.....T. J. HULL  
Assistant Secretary and Exhibition Manager.....R. W. HUFF, JR.  
Technical Committee Secretary.....J. F. VANDER HENST, JR.  
Administrative Assistant  
for Regions and Sections.....G. A. ROLAK  
Publication Director.....NORMAN E. HAMNER  
Editorial Assistant.....DALE MILLER

Inquiries regarding membership, and all general correspondence should be directed to the Executive Secretary at the administrative headquarters of the National Association of Corrosion Engineers at 1061 M & M Building, No. 1 Main Street, Houston 2, Texas.

The National Association of Corrosion Engineers is a non-profit, scientific and research association of individuals and companies concerned with corrosion or interested in it, whose objects are:

- To promote the prevention of corrosion, thereby curtailing economic waste and conserving natural resources.
- To provide forums and media through which experiences with corrosion and its prevention may be reported, discussed and published for the common good.
- To encourage special study and research to determine the fundamental causes of corrosion, and to develop new or improved techniques for its prevention.
- To correlate study and research on corrosion problems among technical associations to reduce duplication and increase efficiency.
- To promote standardization of terminology, techniques, equipment and design in corrosion control.
- To contribute to industrial and public safety by promoting the prevention of corrosion as a cause of accidents.
- To foster cooperation between individual operators of metallic plant and structures in the joint solution of common corrosion problems.
- To invite a wide diversity of memberships, thereby insuring reciprocal benefits between industries and governmental groups as well as between individuals and corporations.

It is an incorporated association without capital stock, chartered under the laws of Texas. Its affairs are governed by a Board of Directors, elected by the general membership. Officers and elected directors are nominated by a nominating committee in accordance with the articles of organization. Election is by the membership.

## Advertising and Editorial Offices of CORROSION

Address all correspondence concerning advertising, circulation and editorial matters relating to CORROSION to the NACE executive offices, 1061 M & M Building, Houston 2, Texas. Inquiries concerning and orders for reprints of technical information published in CORROSION should be sent to this address also.

## OFFICERS and DIRECTORS

### OFFICERS

President.....HUGH P. GODARD  
Aluminum Laboratories, Ltd.,  
Kingston, Ont., Canada  
Vice President.....GEORGE E. BEST  
Allied Chemical Corp.,  
Syracuse, N. Y.  
Treasurer.....A. L. STEGNER  
Tennessee Gas Transmission Co.,  
Houston 2, Texas  
Executive Secretary.....T. J. HULL  
1061 M & M Bldg., Houston 2, Texas

### DIRECTORS

#### Past-President

L. L. WHITEHEAD.....1959-60  
Los Angeles Harbor Dept., San Pedro, Cal.

#### Representing Active Membership

R. McFARLAND, JR.....1958-61  
Hills-McCanna Company, Chicago, Ill.  
E. G. BRINK.....1957-60  
American Viscose Corp., Marcus Hook, Pa.  
J. P. BARRETT.....1959-62  
Pan American Petroleum Corp., Tulsa, Okla.  
E. L. SIMONS.....1959-62  
General Electric Co., Schenectady, N. Y.

#### Representing Corporate Membership

C. G. GRIBBLE, JR.....1958-61  
Metal Goods Corporation, Houston, Texas  
L. C. WASSON.....1958-61  
A. O. Smith Corp., Milwaukee, Wis.  
R. E. KUSTER.....1957-60  
Union Gas Co. of Canada, Ltd.  
Chatham, Ontario, Canada  
R. S. TRESEDER.....1957-60  
Shell Development Co., Emeryville, Cal.  
GUY F. WILLIAMS.....1959-62  
Dowell Incorporated, Tulsa, Okla.

#### Representing Regional Divisions

E. H. TANDY.....(Western) 1958-61  
Standard Oil Co. of California, El Segundo, Cal.  
JOHN B. WEST.....(Southeast) 1957-60  
Aluminum Company of America, Atlanta, Ga.  
F. E. COSTANZO.....(Northeast) 1957-60  
Manufacturers Light and Heat Co., Pittsburgh, Pa.  
E. F. MOORMAN.....(North Central) 1959-62  
International Harvester Co., Chicago, Ill.  
J. C. SPALDING.....(South Central) 1959-62  
Sun Oil Company, Dallas, Texas  
T. R. B. WATSON.....(Canadian) 1959-62  
Corrosion Service Limited, Toronto, Ont., Canada

#### Directors Ex Officio

H. C. VAN NOUHUYS, Chairman Regional  
Management Committee  
908 Boulder Crest Drive, Marietta, Ga.  
R. A. BRANNON, Chairman Policy and Planning  
Committee  
Humble Pipe Line Co., Houston, Texas  
R. S. TRESEDER, Chairman Publications Committee  
Shell Development Co.  
Emeryville, Cal.  
T. J. MAITLAND, Chairman Technical Practices  
Committee  
American Telephone & Telegraph Co., New York,  
N. Y.



## Corrosion of Aluminum Alloy in Glycol-Water Cooling Systems\*

By N. S. DEMPSTER\*

### Introduction

SEVERE CORROSION of aluminum, though non-coupled with copper, can occur if copper is deposited by apparently innocuous waters containing only trace quantities of dissolved copper salts. Several references are made in the literature to this form of galvanic corrosion<sup>1,2,3,4</sup> and the author has found it in aluminum alloy tubes of water-methanol injector systems of aircraft, aluminum components of aircraft fire extinguishers and aluminum finned heat exchanger units of a large air conditioning plant.

The work to be described arose from an investigation of this type of galvanic corrosion in an aircraft oil cooler in which a 30:70 glycol-water mixture was used. This coolant was not inhibited in any way, thus differing from coolants described by Sebba<sup>5</sup> and Thompson,<sup>6</sup> who investigated the severe corrosion of aluminum in glycol-water systems containing triethanolamine phosphate which induced a high copper concentration by amine complex formation.

In the aircraft oil cooler, small nodules of deposited copper (approximately 0.002-inch diameter) were found on the aluminum alloy 52S tubes; their identity was proved by micro-chemical, spectrographic and X-ray diffraction examination. A potential difference of 300 mv was shown between the nodules and the aluminum alloy by a fine electrode probe.

In this paper, mechanism of corrosion is discussed, typical behavior of aluminum alloy 52S in a re-circulating coolant test is described and results are presented of laboratory trials to find satisfactory inhibitors for the system. Compositions of the coolant tubes and of the test panels used are given in Table 1.

### Mechanism of Corrosion

Waters may contain dissolved copper in widely varying concentrations depending primarily on the water composition. Tronstad and Veimo<sup>7</sup> studied the reactions governing copper dissolution and established that the degree of dissolution is dependent on many factors including oxygen concentration, bicarbonate and carbon dioxide concentrations, pH, tempera-

ture and time of contact of water with copper surfaces. The last factor in conjunction with the previous factors will determine film composition on the copper surface and will control copper concentration in solution. A wide range of copper contents of tap waters is quoted in the literature, and values as high as 7 mg/l have been reported.

Wilkins<sup>8</sup> places the critical concentration of copper ions in water at 0.01 ppm. Water containing more than this amount of copper in solution is liable to produce pitting corrosion of aluminum. Wilkins does not clearly state his basis for adoption of a critical concentration of 0.01 ppm. It may be based on actual determination or experience of a threshold value of this order. In discussing metallic deposition on an aluminum surface, Wilkins states that metal will be deposited if the equilibrium potential of a given concentration of metal ions is cathodic to the electrode potential of aluminum. On thermodynamic reasoning, an approximation to the critical concentration can be derived. The values of electrode potential of aluminum in pure water were -0.2 to -0.4 v H<sub>2</sub> scale) although more anodic values must prevail at certain weak spots in the film.

However, if an approximate value of -0.4 v is accepted, reference to the Pourbaix type equilibrium diagram for the Cu-H<sub>2</sub>O system indicates that at a concentration of 10<sup>-15</sup> M Cu<sup>2+</sup> ion, the equilibrium potential is -0.36 v and that thermodynamically copper deposition can occur on aluminum. If a more anodic value than -0.4 v is accepted for local potentials on aluminum, the thermodynamic critical concentration would fall below 10<sup>-15</sup> M Cu<sup>2+</sup> ion. The large discrepancy between the thermodynamically derived critical concentration of 10<sup>-15</sup> M and the value of 0.01 ppm or 1.6 x 10<sup>-7</sup> M stated by Wilkins must be accounted for by consideration of the reaction kinetics.

Corrosion of aluminum alloys by copper bearing aqueous solutions takes place initially by a displacement reaction in which metallic copper is deposited from solution in amount electrochemically equivalent to the quantity of aluminum ions passing into solution. On an aluminum surface immersed in water containing some low concentration of copper ions,

### Abstract

Investigation of galvanic corrosion in an aircraft oil cooler led to tests described in this paper. Corrosion mechanism on aluminum alloy 52S is discussed and results are given of tests designed to find satisfactory inhibitors. Tabular data give inhibitor systems tested. Twenty-two literature references given. Inhibitor tests involved 25 solutions tested. 6.4.2

aluminum ions pass into solution at anodic sites, leaving an excess of electrons on the metal. Copper ions will be discharged at the metal surface by acceptance of electrons.

Wilkins considers that copper ion discharge occurs at anodic areas or weak spots in the oxide film but does not give the mechanism by which this occurs. If cathodic processes are assumed not to occur on the oxide filmed areas of aluminum, initial discharge of copper ions possibly can occur in the following manner.

Within some weak or defect area in the film it can be assumed that there is a variation in the solution tendency of metal atoms depending upon the relative free energy of the atoms at various points of the metal lattice. At the points of higher free energy, the anodic process will occur; at the points of low free energy, the cathodic processes, including copper ion discharge, will occur.

Once copper has been deposited on the metal, a large potential exists between anodic sites and the new cathodic sites. Dissolution rate of aluminum will be greatly accelerated. In the early stages of such a corrosion process, a copper deposit is commonly found at the level of the original metal surface, surrounded by a depression of annular form in which the anodic process of metal ion formation has been occurring.

Pitting is generally associated with this type of corrosion. Once a deep or restricted pit has developed, corrosion can proceed without the influence of the copper cathodes. This is due to differences in aeration and the inability of areas within the pit to heal by oxide film formation.

### Recirculating Coolant Tests

A recirculating coolant apparatus was constructed to determine the effect of dissolved copper on aluminum corrosion in 30:70 glycol-water solutions under flow conditions. The coolant passed over

\*Submitted for publication October 10, 1958.  
\*Australian Defense Scientific Service, Department of Supply, Maribyrnong, Victoria, Australia.

or by-passed copper surfaces before entering a tubular glass cell containing two aluminum alloy 52S panels (3 inches by ¾ inch). A ceramic pump was used to avoid coolant contact with extraneous metals. This test was continued for two weeks with the coolant maintained at 40°C for 7 hours per day for each five-day working week. During the overnight and week-end periods, the system was allowed to cool to room temperature. The pH of all solutions was 6.7.

Copper content of the coolant solutions was determined by polarographic methods before and after each test. At the end of the test period, the aluminum panels were immersed in concentrated nitric acid to remove corrosion products and any copper deposits. Weight loss due to corrosion was determined. Also, copper content of the nitric acid stripping solutions was determined polarographically. Depth of pitting of the aluminum panels was also measured. Results of these recirculating tests are shown in Table 2.

The destructive effect on aluminum specimens caused by recirculating the coolant over copper surfaces is indicated in Table 2. Pitting type corrosion of aluminum occurred when a coolant prepared from freshly distilled ethylene glycol and distilled water was recirculated over copper surfaces. This solution originally contained only 0.06 mg/l copper in solution but after recirculation for 2 weeks contained some 2.5 mg/l, and 8.9 mg of copper had deposited on the aluminum specimens. Table 2 also indi-

cates a significant increase in pit depth and weight loss when Melbourne tap water\* was substituted for distilled water in preparation of the coolant.

Probably the most significant factor contributing to the increased corrosion was 10 to 15 ppm chloride ion in Melbourne tap water. Porter and Hadden<sup>4</sup> indicate that nodular pitting occurs in the simultaneous presence of calcium bicarbonate, chloride, copper salts and oxygen and state that a pitting form of corrosion can occur in distilled water containing 0.04 ppm copper. With a copper content of 2 ppm and in the presence of relatively small amounts of chloride ion, a serious form of pitting was shown to develop.

#### Selection of Inhibitors for Trials

Recirculating coolant tests showed that in glycol-distilled water containing small amounts of copper, a significant amount of pitting corrosion of aluminum alloy 52S will occur. Since pitting can occur in a pure glycol-distilled water coolant, an inhibitive system was necessary to diminish aluminum corrosion or at least to eliminate the pitting form of corrosion. Various inhibitive systems were screened to select the most promising inhibitors from a wide range of formulations collected from literature and others worthy of inclusion on theoretical grounds.

Screening tests were conducted at room temperature, using only distilled water in solution preparation. Solutions were stirred slowly during the 18-week test. Test panels of aluminum alloy 52S were suspended in 500 ml of each solution. Small amounts of copper and 50:50 tin-lead solder turnings were added to each

solution to provide appropriate exposed areas of other materials likely to be present in a coolant system.

It was appreciated that corrosion of the aluminum could be minimized by protective film formation on the copper surfaces to deter copper ion entry into solution, by inhibition of the aluminum surfaces, or a combination of both methods. Sodium mercaptobenzothiazole, which precipitates copper ions from solution, was included in several inhibitor formulations to form a protective film on copper surfaces. For similar reasons, low concentrations of sulphides were used in some solutions.

Inhibition of aluminum corrosion by silicates probably was first established in 1929 by Churchill<sup>9</sup> and has been referred to by many authors<sup>10, 11, 12, 13, 14, 15</sup> and in patents. No reference has been found to the efficacy of silicate inhibition in applications involving chemical displacement of copper ions. Because of the general applicability of silicate inhibition to aluminum alloys and also to copper alloys and lead,<sup>16</sup> several inhibitive systems based on metasilicate and tetrasilicate, alone or in combination with other inhibitors, were included in the trials.

Chromates also were tested at various concentrations, alone and in conjunction with other inhibitors. Mears and Eldredge<sup>17</sup> found that chromate was not satisfactory for inhibition of galvanic couples of aluminum and steel although it was satisfactory for inhibition of aluminum alone in several environments. Darrin<sup>18</sup> reported beneficial effect of metasilicate additions to chromate solutions in inhibiting aluminum corrosion when coupled to copper, but metasilicate without chromate was not effective.

Wormwell, Mercer and Ison<sup>17</sup> refer to variable results on RR 50 aluminum alloy when using 1.5 percent sodium benzoate plus 0.1 percent sodium nitrite inhibition in glycol solutions. Wormwell and Mercer<sup>18</sup> showed that an increased sodium benzoate concentration of 5 percent satisfactorily inhibited solder.

Attention also has been given to the use of concentrated benzoate solutions in coolant systems.<sup>19</sup> They are reported to be satisfactory with duralumin and solder and can be used instead of glycol solutions because of the freezing point depression by benzoate. Solutions containing 1.5 percent sodium benzoate plus 0.1 percent sodium nitrite, 2, 5 and 20 percent sodium benzoate were included in the trials. One author<sup>19</sup> referred to satisfactory inhibition by guanidine carbonate in glycol coolants and although guanidine carbonate should behave similarly to many amines in increasing the copper ion concentration in solution, causing an acceleration of corrosion of aluminum, this inhibitor at the recommended concentration was included in the tests.

Use of borates and phosphates has been suggested for inhibition of glycol coolant systems.<sup>20</sup> One percent borax in glycol solutions inhibits corrosion of several metals at elevated temperatures; at low temperatures, borax increases the corrosion of zinc, cadmium, brass and magnesium but does not accelerate corrosion of copper, lead or aluminum.<sup>20</sup>

\* Analysis (ppm): Ca 2.5, Mg 1.5, Na 7, K 2, HCO<sub>3</sub> 10, SO<sub>4</sub> 2, Cl 10-15, NO<sub>3</sub> 1. Hardness (ppm CaCO<sub>3</sub>): temporary 8, permanent 4.

TABLE 1—Composition of Aluminum Alloy Coolant Tubes and Test Panels

Element	Specification Alcoa 52S	Coolant Tubes	Test Panels
Magnesium	2.2-2.8%	2.4%	2.4%
Chromium	0.15-0.35%	0.26%	0.26%
Iron + Silicon	0.45% max.	0.31%	0.38%
Manganese	0.1% max.	faint trace	trace (<0.02%)
Copper	0.1% max.	trace	trace (<0.05%)
Zinc	0.03% max.	Nil	Nil
Other impurities	0.03% max. each 0.1% max. total	Titanium, faint trace	Titanium, faint trace
Aluminum	remainder	remainder	remainder

TABLE 2—Recirculating Coolant Tests of 30:70 Glycol-Water with Aluminum Alloy 52S

Test	Solution	Weight Loss per 4.5 In <sup>2</sup> of Aluminum Alloy 52S	Pit Depth		Weight of Copper Deposited on each Aluminum Alloy Specimen	Copper Content of Solution	
			Average	Maximum		Before Test	After Test
1. No copper surfaces in circuit	30:70 glycol-tap water	g 0.002	112	480	mg 0.06	mg/l 0.3	mg/l —
2. No copper surfaces in circuit	30:70 glycol-distilled water	0.001	No pits visible		0.02	0.06	—
3. Copper surfaces in circuit	30:70 glycol-distilled water	0.003	113	260	4.4	0.06	2.5
4. Copper surfaces in circuit	30:70 glycol-tap water	0.008	250	750	4.5	0.35	1.7

TABLE 3—Inhibitor Trials of 30:70 Glycol-Water Solutions (Second Series)

Inhibitor	Solvent*	pH		Weight Loss of Aluminum Alloy mg
		Initial	Final	
1. No inhibitor.....	G.D.W.	6.5	5.7	59.8
2. No inhibitor Neither copper nor solder in system.....	G.D.W.	7.1	5.8	3.0
3. No inhibitor.....	D.W.	6.6	6.4	4.7
4. No inhibitor.....	G.T.W.	6.7	6.9	121.7
5. No inhibitor.....	T.W.	6.9	6.9	23.0
6. Sodium metasilicate 0.1% (pH reduced to 9.9 with phosphoric acid).....	G.D.W.	9.9	8.9	34.8
7. Potassium chromate 0.3%....	G.D.W.	8.1	9.0	24.2
8. Sodium tetrasilicate 0.1%.....	G.D.W.	9.5	7.8	57.2
9. Sodium tetrasilicate 0.1% + borax 1%.....	G.D.W.	9.1	8.7	Nil
10. Potassium chromate 5%.....	G.D.W.	9.1	9.6	1.0
11. Sodium benzoate 20%.....	G.D.W.	7.0	6.9	2.7
12. Tannic acid (pH adjusted to 7.5 with sodium hydroxide).....	G.D.W.	7.5	4.9	58.1
13. Potassium chromate 0.3% + sodium metasilicate 0.1% (pH reduced to 9.6 with phosphoric acid).....	G.D.W.	9.6	8.8	+0.8
14. Sodium benzoate 5%.....	G.D.W.	6.3	6.3	9.6
15. Sodium benzoate 2%.....	G.D.W.	6.2	6.1	1.4

Inhibitor	Solvent*	pH		Weight Loss of Aluminum Alloy mg
		Initial	Final	
16. Sodium cinnamate 2%.....	G.D.W.	7.6	7.7	0.6
17. Sodium tungstate 0.1% + sodium molybdate 0.1%.....	G.D.W.	7.0	7.9	17.2
18. Sodium tungstate 1% + sodium molybdate 1%.....	G.D.W.	8.4	7.7	8.3
19. Sodium metasilicate 0.5% (pH reduced to 10.0 with phosphoric acid).....	G.D.W.	10.0	9.2	0.5
20. Sodium benzoate 2% + sodium metasilicate 0.1% (pH reduced to 9.9 with phosphoric acid)....	G.D.W.	9.9	7.5	0.4
21. Sodium cinnamate 2% + sodium metasilicate 0.1% (pH reduced to 9.9 with phosphoric acid)....	G.D.W.	9.9	7.6	0.9
22. Sodium tungstate 1% + sodium molybdate 1% + sodium metasilicate 0.1% (pH reduced to 9.7 with phosphoric acid).....	G.D.W.	9.7	7.7	Nil
23. Tannic acid 1% + sodium metasilicate 0.1% (pH adjusted to 9.9).....	G.D.W.	9.9	6.3	2.0
24. Sodium tungstate 1% + sodium molybdate 1% + sodium tetrasilicate 0.1% (pH reduced to 9.5 with phosphoric acid).....	G.D.W.	9.5	7.6	Nil
25. Sodium cinnamate 2% + sodium tetrasilicate 0.1% (pH reduced to 9.5 with phosphoric acid)....	G.D.W.	9.5	7.2	Nil

\* G.D.W. = glycol-distilled water. G.T.W. = glycol-tap water.  
D.W. = distilled water. T.W. = tap water.

### Results of Inhibitor Trials

#### First Series (Screening Tests Using Distilled Water)

Silicate based inhibitors which proved satisfactory included 0.1 percent sodium metasilicate, 0.1 percent sodium metasilicate plus 0.3 percent sodium mercaptobenzothiazole, 0.1 percent sodium tetrasilicate, 0.1 percent sodium tetrasilicate plus 1 percent borax and 0.1 percent metasilicate plus 0.3 percent potassium chromate.

A large precipitate formed in all solutions containing sodium mercaptobenzothiazole, and only two of the five solutions containing this compound proved sufficiently inhibitive to aluminum. Both solutions also contained silicates, but they were not tested in further trials because formation of a precipitate from solution was considered undesirable.

The use of sulfides failed because of the non-protective nature of the copper sulfide film. If the sulfide concentration was maintained at 0.01 percent, the copper turnings were corroded by progressive sulfide film formation.

The following chromate solutions effectively inhibited corrosion of the aluminum alloy: 0.3 percent potassium chromate, 5 percent potassium chromate, 0.3 percent sodium chromate plus 0.5 percent sodium borate plus 0.1 percent sodium nitrite and 0.3 percent potassium chromate plus 0.1 percent sodium metasilicate.

Of the solutions containing benzoate, 1.5 percent sodium benzoate solution plus 0.1 percent sodium nitrite caused pitting in two areas. The 2 percent and 5 percent sodium benzoate solutions inhibited corrosion, but with the 20 percent solu-

tion, some pitting of specimens occurred above the meniscus because of creep and drying out of the benzoate.

Guanidine carbonate accelerated the corrosion.

A 1 percent borax solution was not an effective inhibitor, but addition of 1 percent borax to a 0.1 percent sodium tetrasilicate solution materially improved the performance of the latter.

A 2 percent solution of sodium cinnamate was an effective inhibitor. Solutions containing sodium tungstate plus sodium molybdate were partially effective.

#### Second Series (Glycol-Distilled Water)

Inhibitor formulations which performed satisfactorily in the room temperature tests without presence of glycol were tested in 30:70 distilled ethylene glycol-distilled water solutions. Test panels of aluminum alloy 52S were suspended in 300 ml of each solution, and small amounts of copper turnings and 50:50 tin-lead solder turnings were added to each solution as before.

This second test series was conducted for nine weeks with temperature maintained at 95 C, 7 hours per day for each 5-day working week. During the overnight and week-end periods, the solutions were allowed to cool to room temperature.

Results of the second test series are presented in Table 3. For determination of weight losses after test, the panels were immersed for two minutes in concentrated nitric acid at room temperature. In a few instances, it was necessary to follow the nitric acid pickle by treatment in a solution containing 5 percent phosphoric acid plus 2 percent chromic acid at 80 to 85 C. Appropriate blank

corrections were applied to the weight loss values.

Tests 1 to 5 show not only the detrimental effect of copper but also a marked increase in corrosion caused by ethylene glycol. A similar observation has been noted in the literature.<sup>10</sup> The appearance of the copper in these tests suggested that glycol may destroy the oxide film normally formed on copper in aqueous media, thereby increasing the copper ion concentration in solution.

Silicate based solutions 6 and 8 gave satisfactory performance for three weeks, then breakdown occurred with etching of the aluminum. Solution 19 (0.5 percent metasilicate) was satisfactory for eight weeks. In each of these cases and in the silicate bearing Solutions 20, 21, 22, 24 and 25, a considerable decrease in pH occurred during the test. Solution 9 (sodium tetrasilicate-borax) showed the buffering effect of borax in lessening the decrease in pH, and inhibition of aluminum was satisfactory. Some corrosion of the solder occurred although this may be eliminated by increasing the silicate concentration.

In the first series of tests conducted in non-glycol containing solutions at room temperature, solutions containing chromate satisfactorily inhibited corrosion of aluminum. Although some reduction of chromate would occur in glycol, three of these systems were included in the schedule. Solution 10 was particularly satisfactory in inhibiting corrosion of aluminum, copper and solder, but the reduction of chromate produced a green precipitate (chromium hydroxide) which could have harmful effects in cooling systems.

Satisfactory inhibition of aluminum in



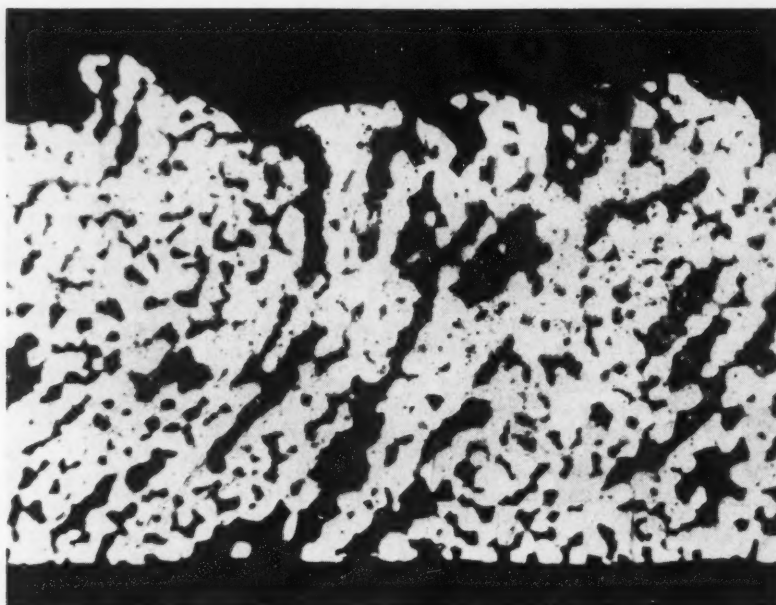


Figure 1—Microstructure of 50:50 tin-lead solder corroded by 20 percent sodium benzoate solution. Corrosion has taken place preferentially in the lead-rich  $\alpha$  phase.

an ethyl alcohol-water solution using potassium dichromate has been reported,<sup>23</sup> but the concentration of dichromate was reduced to one-third the original in 16 days with most reduction occurring in the first two or three days. In the present tests on a 30 percent ethylene glycol solution, initial concentration of 4.7 percent potassium chromate was reduced to 4.2 percent after 15 days at operation temperature of the second trial series. While reduction of chromate was limited, precipitate formation was considered undesirable.

Of the organic inhibitors tested, cinnamate (Solution 16) seems the most promising for aluminum but produced a pustular form of corrosion product on copper. The 20 percent sodium benzoate solution caused extreme embrittlement of the solder, but no obvious embrittlement was observed with the 5 and 2 percent benzoate solutions. Metallographic examination showed that the solder sample in 20 percent benzoate solution was severely affected by preferential  $\alpha$  phase corrosion (see Figure 1). There was comparatively minor preferential  $\alpha$  phase corrosion also in the 5 and 2 percent solutions.

Brittleness of the solder turnings was noted also in the first series (distilled water) tests, being most severe with the

20 percent benzoate solution and least severe with the 2 percent solution. Metallographic examination confirmed that the extent of preferential  $\alpha$  phase corrosion diminished with decreasing benzoate concentration.

Wormwell and Mercer<sup>18</sup> stated that soldered joints remained unattacked for over two years in glycol solutions containing 5 percent sodium benzoate. Fourteen-day thermo-syphon tests by Vernon et al<sup>21</sup> showed that a 30 percent solution of sodium benzoate was virtually non-corrosive toward solder. In the present tests in which solder turnings were only 0.005 inch thick, detection of preferential corrosion of one alloy phase would be easier than in the case of soldered joints.

Benzoate solutions were prone to creep and caused some etching of the aluminum alloy above the liquid level. Vernon also refers to sodium benzoate creep but found it non-corrosive to duralumin.

Some incidental tests were conducted on anodized aluminum alloy 52S sealed with various inhibitors in a manner similar to that used by Whitby.<sup>22</sup> Confirming the results reported above, these tests showed that silicate sealing of the anodized coatings was most effective. Thick films produced by the sulphuric acid process were naturally better than the chromic acid process coatings, primarily because

they permitted greater absorption of silicate inhibitor.

### Conclusions

These tests have shown the remarkable sensitivity of an aluminum alloy to corrosion in a 30:70 glycol-water mixture when the latter contains trace amounts (0.3 to 2 ppm) of copper in solution. This applies to redistilled glycol-distilled water mixtures. Marked corrosion accentuation occurred if the distilled water was replaced by fairly pure tap water containing only 10 to 15 ppm chloride.

On the basis of laboratory trials conducted on a cyclic temperature basis in ethylene glycol-distilled water mixtures, two inhibitive systems based on (1) sodium tetrasilicate plus sodium tetraborate and (2) sodium tetrasilicate plus sodium tetraborate plus sodium cinnamate can be recommended for service trials.

### Acknowledgments

This paper is published by permission of the Chief Scientist, Australian Defense Scientific Service, Department of Supply, Melbourne, Australia.

The author wishes to express his appreciation to A. G. Sussex for assistance in preparation of this paper and to acknowledge the assistance of P. J. Knuckey in the experimental work.

### References

1. L. Tronstad and R. Veimo. *J Inst Met*, 66, 17-32 (1940).
2. D. W. Sawyer and R. H. Brown. Resistance of Aluminum Alloys to Fresh Waters. *Corrosion*, 3, 443 (1947) Sept.
3. F. C. Frary. *Trans Amer Inst Chem Engrs*, 31, 3-16 (1935).
4. G. H. Botham and W. R. Bryson. *J Dairy Res*, 20, 154-155 (1953).
5. F. Sebba. Report CH416. Farnborough: Royal Aircraft Establishment, 1945.
6. P. F. Thompson. Report ACA-24. Melbourne: Australian Council for Aeronautics, 1946.
7. N. J. M. Wilkins. Report M/R 1296. Harwell: Atomic Energy Research Establishment, 1953.
8. F. C. Porter and S. E. Hadden. *J Appl. Chem*, 3, 385-409 (1953).
9. H. V. Churchill. *Trans AIME, Inst Met Div*, 83, 244-247 (1929).
10. R. W. Mitchell. *Metal Ind*, 28, 171-172 (1930).
11. H. Lichtenberg. *Aluminium Berl*, 19, 504-509 (1937).
12. G. G. Eldredge and R. B. Mears. *Ind Eng Chem*, 37, 736-741 (1945).
13. W. Stericker. *Ind Eng Chem*, 30, 348-351 (1938).
14. J. M. Bryan. *J Soc Chem Ind (London)*, 69, 169-173 (1950).
15. R. B. Mears and G. G. Eldredge. *Trans Electrochem Soc*, 83, 403-417 (1943).
16. M. Darrin. *Ind Eng Chem*, 37, 741-749 (1945).
17. F. Wormwell, A. D. Mercer and H. C. K. Ison. *J Appl Chem*, 3, 133-144 (1953).
18. F. Wormwell and A. D. Mercer. *J Appl Chem*, 3, 22-27 (1953).
19. *Light Metals*, 12, 165-168 (1949).
20. D. Caplan and M. Cohen. Accelerating Effect of Decreasing Temperature on Corrosion by Glycol Solutions. *Corrosion*, 9, 284 (1953). Aug.
21. W. H. J. Vernon, F. Wormwell, E. G. Stroud and H. C. K. Ison. *Bulletin 4*, pp. 16-21, Brentford: Motor Industry Research Association, 1948.
22. L. Whitby. *Metal Finish*, 46, No. 9, 70-74 (1948).

Any discussion of this article not published above will appear in the December, 1959 issue



# Notch Sensitivity Effects in Stress Corrosion and Hydrogen Embrittlement Tests on High Strength Steels\*

By B. F. BROWN

## Introduction

THERE ARE no universally accepted tests for determining susceptibility to stress-corrosion cracking or to hydrogen embrittlement. In most cases the evaluation of these properties is sought in tests in which, if complete fracture of the specimen occurs, the measurement reported is the time for rupture. The purpose of this paper is to show how in some instances this test procedure can give erroneous impressions of the rate of cracking by stress-corrosion or by hydrogen embrittlement. To show this requires first a consideration of the fracture behavior of these steels under purely mechanical conditions.

## Behavior of High-Strength Steels in Notch-Sensitivity Tests

Various segments of industry are becoming aware—sometimes at considerable expense—that structures fabricated from high-strength steels\* may shatter by brittle fracture in proof-testing at a small fraction of the design stress. The reason for this behavior appears to be a combination of (a) notches, cracks, flaws, or other stress-raisers and (b) steel characteristics because of which the effective strength of the steel is seriously lowered by the presence of a stress raiser.

The notch sensitive characteristics of a steel cannot be anticipated from the behavior of the steel in conventional tensile tests, regardless of how these tests are conducted and interpreted. In order to determine how the steel will behave under stress in the presence of a stress raiser, it is necessary to conduct a special test, usually one in which the specimen contains a suitable notch. Such a test, as developed and applied at the U. S. Naval Research Laboratory,<sup>1</sup> makes use of a conventional sheet tensile specimen in which a sharp central crack is introduced. The specimen is pulled to fracture and the results are expressed as net fracture stress.

It is observed that the net fracture stress exhibits a transition from high to low values when the test temperature is lowered sufficiently (Figure 1). This transition is commonly accompanied by a change in fracture appearance from shear to shear-plus-brittle to all-brittle fracture. In the shear-plus-brittle range

## About the Author



B. F. BROWN is head of the Physical Metallurgy Branch, U. S. Naval Research Laboratory, Washington, D. C. Formerly he held research posts at North Carolina State College, Massachusetts Institute of Technology, and Carnegie Institute of Technology. He received degrees in metallurgy from Carnegie Institute of Technology (DSc, MS) and the University of Kentucky (BS).

the shear zone appears as a lip at the surfaces of the specimen.

The transition temperature thus determined is strongly dependent upon such metallurgical variables as composition and heat treatment. For a given composition and heat treatment, the transition temperature as determined in such a test is also affected strongly by specimen shape and size: It is possible to decrease the transition temperature 200 F by reducing the specimen thickness from 0.041 inch to 0.010 inch.<sup>2</sup> The steel used throughout the study reported here was the same as used to derive the curves in Figure 1 and was a constant thickness.

Thus if one is stressing at a sufficiently high level a specimen which is notch sensitive by reason of composition, heat treatment, thickness and temperature, and a sharp notch is introduced, the specimen can be expected to rupture at stresses much lower than anticipated by the tensile test. A stress-corrosion crack might be expected to produce just such a sharp notch.

One can then deduce from Figure 1 that if a specimen of this steel tempered at 900 F is subjected to stress-corrosion attack near room temperature, under a constant load corresponding initially to one-half the yield strength, the amount of true stress-corrosion cracking would not be expected to be extensive before the remainder of the specimen broke abruptly in brittle fracture. The continuous curve in Figure 1 shows the properties of a steel of similar composition

## Abstract

The various high-strength steels differ from each other in their resistance to brittle fracture under stress in the presence of a notch; this property, called notch sensitivity, also varies with heat treatment. It is shown that this purely mechanical phenomenon may terminate a stress-corrosion test in such fashion as to give an erroneous impression of the rate of stress-corrosion cracking.

Extensive fracture strength data are reported on modified Type 422 steel specimens tempered at 875 F and 1075 F and stress corrosion cracked. Crack growth behavior for 11 specimens is shown graphically. 3.2.2

which was tempered at 1050 F. Two points are to be noted here: considerably more stress-corrosion (under the same initial stress) would be required before the stress on the uncorroded cross-section attains the room temperature net fracture stress, and since the room-temperature fracture of the center-cracked specimen was ductile (shear) fracture, the terminal fracture of the stress-corrosion specimen would be expected to be a shear fracture.

Therefore, if a specimen heat-treated to be notch sensitive is placed in a stress-corrosion test under an initial stress of 100 ksi, one would expect it to rupture as soon as the stress-corrosion crack had grown large enough to become an effective notch. But a specimen heat-treated to be notch-insensitive under the same initial stress would have to undergo a great deal of stress-corrosion—roughly half the cross section—before the stress exceeded the net fracture stress. (It should be noted that not only the extent of cracking but also the geometry of crack area would be expected to influence the onset of terminal fracture.) In other words, failure of a notch-tough specimen in a stress-corrosion test under constant load is expected to represent much more extensive stress-corrosion than failure of a notch-sensitive specimen under the same conditions.\*\*

The foregoing represents the behavior to be expected in stress-corrosion tests of high-strength steels. In order to check these expectations experimentally it is necessary to distinguish between the stress-corrosion and the purely mechanical fractures.

\*\* Specimens for the present study were not available in precisely the same heat treatment as those of Reference 2 from which Figure 1 was taken. Extensive experience in the field of crack propagation in steels of this general class, however, has demonstrated consistently that decreasing the tempering temperature from 900 F to 875 F increases the notch brittleness, and that increasing the tempering temperature from 1050 F to 1075 F increases the notch toughness: in short, the tempering treatments for the stress corrosion specimens would give even greater difference in transition temperature than is shown in Figure 1.

\* Submitted for publication January 6, 1959.

\* The term "high-strength" steels here refers to those steels, martensitic or precipitation-hardening, low-alloy or "stainless," which have yield strengths exceeding about 180 ksi.

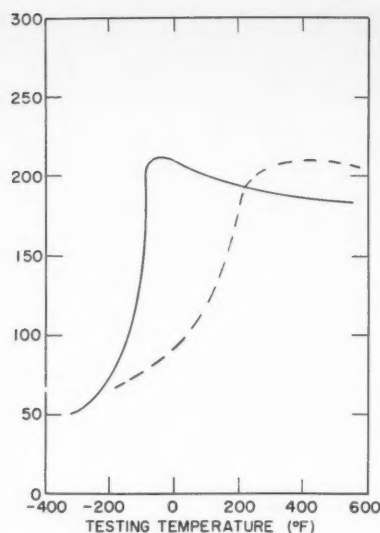


Figure 1—Effect of temperature on the net fracture stress of modified Type 422 steel tempered at 900 F (broken curve) and 1050 F (continuous curve). Center-cracked strip specimens were 0.040-inch thick. (From Reference 2.)

### Distinguishing Mechanical Fracture From Stress-Corrosion Fracture

Shear fracture can sometimes be distinguished from a stress-corrosion crack by metallographic examination of the cross section, in which the shear fracture may exhibit near the fracture surface signs of the plastic deformation which is responsible for the high energy absorption associated with this mode of fracture. In some cases, however, this plastically-deformed zone may be so thin as to be difficult to identify with confidence. An effort has been made in this laboratory to distinguish by metallographic section between brittle-fracture and stress-corrosion cracking in these high-strength sheet steels, but reliable diagnostic metallographic criteria for the general case have not been developed.

On the macroscopic scale, however, there has long existed a type of fracture appearance which positively identifies brittle fracture. This feature, which has come to be known as "chevron markings," may be seen in Figure 2; the chevrons are attributed to stoppage and reinitiation of brittle fracture,<sup>4</sup> and they always point to the origin of fracture. (Appearances of fracture surfaces are particularly difficult to capture photographically, and none of the photographs reproduced here illustrate the noted characteristics as clearly as the eye sees in the original specimen.)

Brittle fractures, once initiated, propagate at speeds roughly one-third the speed of sound in the metal. No evidence appears to have been found to indicate that a stress-corrosion crack propagates at anything approaching this speed. It

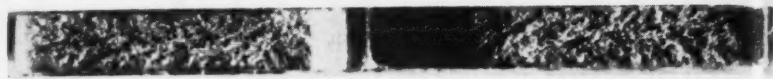


Figure 2—Fracture surface of center-cracked specimen broken in tensile machine below its transition temperature. Chevron markings on the brittle-fracture surface point toward the initial center crack. (9X)

appears reasonable to accept tentatively very high rates of propagation, by which is meant rates higher than can be measured by eye, as an additional criterion for brittle fracture.

### Experiments on Mechanical Fracture in Stress-Corrosion Specimens Under Tension

Flat strip specimens were held in tension by wedge grips in a stress-rupture machine and exposed to corrodent. If the entire specimen was exposed, the slight bending moment introduced by imperfect alignment caused fracture to initiate at one edge, as indicated by the chevron markings of Figure 3. In order to cause fracture to initiate at the center of the specimen, to be able to compare fracture appearance with the center-cracked notch-sensitivity specimens, three schemes were used:

(1) The specimens were masked with stop-off lacquer everywhere except for a central panel, which was exposed to the corrodent.

(2) A wick was used to bring the corrodent to a single centrally-located spot on the specimen, which was otherwise not in contact with corrodent.

(3) Holes were drilled on the centerline of the specimen, which was then exposed to the corrodent; these holes provided sufficient stress concentration to ensure that fracture initiated at the center.

Although the chevron markings and shear lips on such specimens clearly defined much of the fracture as purely mechanical, the exact extent of the purely stress-corroded crack could not be established. To accomplish this two holes 0.076 inch in diameter were drilled on the centerline with centers one inch apart. The purpose of these holes was again to ensure that stress-cracks initiated at the center rather than at the edge but secondly to produce two sets of cracks which it was hoped would grow at about the same rate. Each specimen was then stressed under constant tensile

load in corrodent\* until it broke through one of the holes. It was then baked at least four hours at 450 F, which served both to remove corrodent and hydrogen and to heat-tint the stress-corrosion cracks at the hole through which the specimen had not broken. The specimen was then pulled to fracture in the tensile machine.

The loads required to break the specimen through the second hole averaged about 3 percent, and were never as much as 10 percent higher than those imposed in the stress-corrosion part of the experiment, as may be seen in Table 1. This is taken to indicate that the size and distribution of stress-corrosion crack areas in the two holes of a given specimen were reasonably near the same, and that therefore the heat-tinted areas listed in the table represent a fair estimate of the extent of stress-corrosion cracking which occurred prior to terminal mechanical fracture through the first hole.

Figure 4 shows fractures of sets of specimens tested as above. Figure 4a shows the fracture through one hole of a notch-sensitive specimen subjected to a stress-corrosion cracking test at 100,000 psi initial nominal stress and just below it (Figure 4b) the tensile fracture through the remaining hole; the discolored area near the central hole is the heat-tinted zone. (The dark areas on the extreme right of Figure 4b are lighting effects.)

Figure 4c shows the fracture through one hole of a notch-insensitive specimen under the same conditions as 4a, while 4d shows the tensile fracture. In both Figures 4c and 4d it can be seen that the stress-corrosion cracks ran completely across one side of the specimen and halfway across the center of the opposite side.

At the higher stress (150,000 psi initial nominal stress) the brittle specimen again showed only a small stress-corrosion crack in the second hole when rupture occurred through the first hole, but the notch-insensitive specimen showed considerable cracking.

### Fracture of Bent-Beam Specimens

The fact that brittle fracture can occur during a stress-corrosion test conducted with the specimen under tension does not require of course that it occur in a specimen loaded in bending. Specimens of the same modified Type 422 stainless steel were observed therefore for cracking behavior when bent and exposed to the standard corrodent. The specimens were tempered at 875 F in

\* The corrodent used throughout this study was 1 percent acetic acid in distilled water saturated with NaCl, de-aerated by an aspirator pump, and then saturated with H<sub>2</sub>S. In the tensile stress-corrosion tests the container surrounding the specimen was completely filled with solution and sealed with paraffin wax to minimize loss of H<sub>2</sub>S. Strictly speaking it is not known whether this solution causes cracking by stress-corrosion (an anodic process), or by hydrogen embrittlement (from a cathodic process). This could be determined readily but is unimportant to the essential thesis, which is that brittle fracture may terminate a fracture in these steels regardless of the mechanism responsible for initiating the fracture.



Figure 3—Fracture surface of "stress-corrosion cracking" specimen broken under constant tensile load. Note chevron markings which cover most of the fracture surface and point to the left, indicating that brittle fracture initiated at left edge and propagated across entire specimen. Grayish zones of varying thickness can be seen along both sides; these are typical shear lips and are of purely mechanical origin.

transition  
crack. (9X)

through  
baked at  
a served  
hydrogen  
corrosion  
which the  
specimen  
the ten-

the speci-  
averag-d  
as much  
imposed  
experi-  
1. This  
ize and  
n crack  
n speci-  
me, and  
as listed  
mate of  
cracking  
ual me-  
st hole.  
sets of  
ure 4a  
hole of  
ected to  
100,000  
t below  
acture  
the dis-  
e is the  
on the  
lighting

through  
specimen  
, while  
n both  
en that  
pletely  
d half-  
opposite

psi ini-  
specimen  
g-corro-  
en rup-  
le, but  
showed

mens  
re can  
st con-  
tension  
occur  
Speci-  
oe 422  
ore for  
nd ext-  
t. The  
F in

fracture  
ness can

(a) Fracture which occurred during stress-corrosion test on specimen tempered at 875 F.

(b) Tensile fracture through remaining hole of same specimen; very small darkened area near central hole indicates limited amount of stress-corrosion cracking which occurred before mechanical fracture commenced.

(c) Fracture which occurred during stress-corrosion test on specimen tempered at 1075 F.

(d) Tensile fracture through remaining hole of same specimen; darkened band shows that a stress-corrosion crack had progressed completely across one face and partially across the opposite face before mechanical fracture commenced.

Figure 4—Fracture surfaces of two-hole specimens:

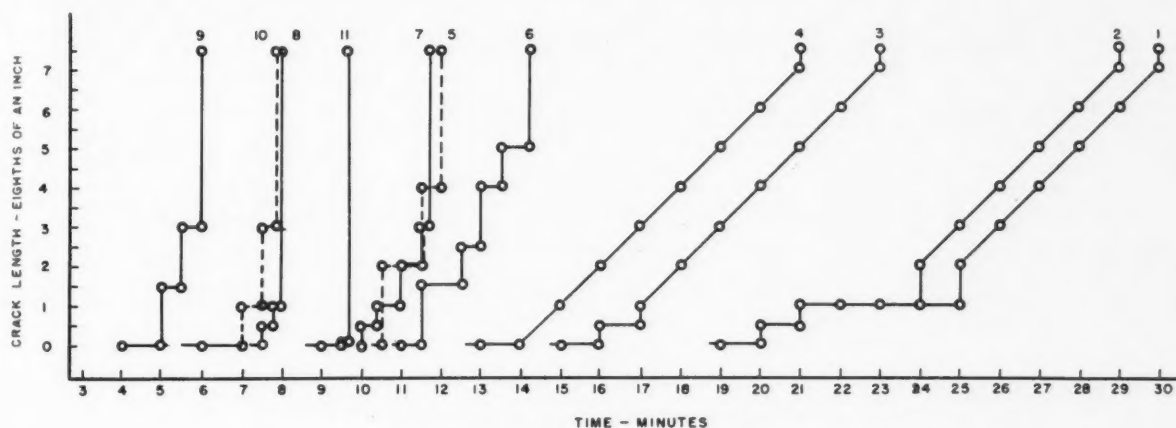


Figure 5—Crack propagation in bent strip specimens at various stress levels immersed in corrosive.

TABLE 1—Net Fracture Strengths of Two-Hole Specimens Previously Stress-Corrosion Cracked to Rupture Through One of the Holes

Specimen No.	Tempering Temp.	Stress-Corrosion			Tensile		
		Load (lb)	Nominal Stress (psi)	Time to Fracture (hrs)	Max. Load (lb)	Max. Load/Residual area (psi)	Area Heat-Tinted (Sq. in)
1.....	875 F	3600	100,000	0.2	3600	118,000	0.0054
2.....	1075 F	3600	100,000	1.3	3300	173,000	0.0170
3.....	875 F	5400	150,000	0.1	5600	164,000	0.0018
4.....	1075 F	5400	150,000	0.7	5700	238,000	0.0120
5.....	875 F	5400	150,000	0.1	5350	169,000	0.0043
6.....	1075 F	5400	150,000	0.5	5450	194,500	0.0070

Notes: Tensile properties without drilled holes, as tempered (a) 875 F: 250,000 psi ultimate, 167,000 psi yield.  
Tensile properties without drilled holes, as tempered (b) 1075 F: 210,000 psi ultimate, 166,000 psi yield.  
Tensile properties with drilled hole, as tempered (a) 875 F: 211,000 psi ultimate.  
Tensile properties with drilled hole, as tempered (b) 1075 F: 187,000 psi ultimate.  
These two tempering temperatures were selected to accentuate the difference in transition temperature anticipated from Figure 1.

order to be notch sensitive. They were 1/16ths of an inch wide by 0.040 inch thick and 8 inches long; specimens were stressed by being bent and held in a bakelite fixture. A small sharp notch was filed at the edge of the specimen at its mid-length in order to promote the nucleation of a single crack during expo-

sure, and a scale was scribed on the specimen with points one-eighth of an inch apart along a traverse parallel to and near the expected fracture path. The specimen was then immersed in the corrosive, which was contained in a glass beaker. The progress of fracture was monitored with the aid of a hand

lens. The length of crack on the tension side was readily observable not only because of the tendency for such a crack to open up but also because of the stream of small hydrogen bubbles which were discharged from the cracked area.

The specimens were under constant observation, but measurements of crack



length were recorded only at one-minute intervals if the crack were growing continuously, and additionally at the time of a jump if growing discontinuously. The crack growth behavior for 11 specimens is shown graphically in Figure 5. Specimen 1 was the only one stressed within the elastic limit and was bent so that the chord of the arc was  $7\frac{1}{16}$  inches long; the stresses increase with increasing specimen number, the chords of the remaining specimens being as follows:  $7\frac{3}{16}$ ,  $7\frac{1}{4}$ ,  $6\frac{3}{4}$ ,  $6\frac{1}{4}$ ,  $6\frac{1}{8}$ , 6,  $5\frac{7}{8}$ ,  $5\frac{3}{4}$ , and  $5\frac{1}{4}$  inches.

It will be seen in Figure 5 that although in a general way higher stresses have tended to produce shorter incubation times, there are many exceptions to this, presumably caused by poor reproducibility of the small initial filed notch. No concern was felt for this, however, since the rate of growth of the crack rather than its incubation time was the significant thing to watch.

It was concluded from the data of Figure 5 that for specimens 1 through 3 the stress was sufficient to initiate brittle fracture from an undetectably small stress-corrosion crack. It also was determined for these specimens that the stress was insufficient to propagate the brittle fracture far before it was arrested by some unspecified metallurgical barrier, and that thenceforward the cracking occurred by stress-corrosion cracking in these specimens. In specimen 4 all the fracturing appears to be by stress-corrosion cracking, with the exception of the small amount of fast terminal fracture observed in all specimens. At stresses higher than that of specimen 4, the fractures occurred by a series of brittle-fracture segments; presumably the metal-

lurgical barriers which arrest these brittle fractures are removed by stress-corrosion. In general, the higher the stress, the less likelihood that the fracture once initiated will be stopped, so that in specimen 11, after a small crack had appeared, the remainder of the specimen fractured in a single run.

The interpretation of the rate curves is as follows: For specimens 1 through 4 some process not involving stress intensity, perhaps a diffusion process, is the rate-limiting process in stress-corrosion cracking at these stress levels. The discontinuous change in crack propagation rates, a change which amounts to at least three orders of magnitude, surely indicates a fundamental change of cracking mechanism, and the most likely mechanism to account for both the observed high propagation rate and the observed low ductility is conventional brittle fracture. In confirmation of this, the fracture surface was observed to contain a thin irregular shear lip on the tensile surface and resembled in all details a specimen of the same steel bent to fracture in the absence of corrodent.

### Discussion

It is thus apparent that under some conditions a great part of a fracture occurring in a stress-corrosion test specimen can be produced by purely mechanical action.

For the materials user, rupture of a given material after short exposure appears sufficient for the practical purpose of rejecting the material without distinguishing between stress-corrosion cracking and brittle fracture; it should be noted however that this could sometimes lead to rejection, because of extreme

notch sensitivity, of material which cracks by stress-corrosion only very slowly and which in other geometries and other stress configurations might not be susceptible to brittle fracture. If the materials user observes absence of cracking in specimens of a given material, this would suffice for tentative acceptance from the standpoint of stress-corrosion cracking, although of course it says nothing about notch sensitivity.

It is really the materials producer who has the greater stake in separating the two modes of fracture. For it is unlikely that in the general case variations in heat treatment and in alloy composition will affect the susceptibilities to the two modes of fracture in the same way. When the time arrives that the metallurgical variables controlling these two types of failure are better understood, the improvement of a given material will be more expeditious if one assesses the two properties separately.

### Acknowledgment

The author wishes to record his appreciation for the services of R. Newbegin, who conducted most of the experimental work, and of G. Sandoz, who contributed partial supervision of the experiments as well as valuable suggestions.

### References

1. J. E. Srawley and C. D. Beachem. Crack Propagation Tests of High-Strength Sheet Steels Using Small Specimens. NRL Report 5127, 9 April 1958.
2. J. E. Srawley and C. D. Beachem. Crack Propagation Tests of Some High-Strength Sheet Steels. NRL Report 5263 (1959).
3. J. E. Srawley and C. D. Beachem. Gases in Steel (Crack Sensitivity of High-Strength Sheet Steels). Report of NRL Progress, August 1958, p. 27.
4. C. F. Tipper. The Study of Fracture Surface Markings. *J. Iron and Steel Inst.*, 183, 4-9 (1957).

Any discussion of this article not published above will appear in the December, 1959 issue

which  
ly very  
metries  
ght not  
If the  
f crack-  
material,  
accept-  
ess-cor-  
urse it  
ity.

er who  
ing the  
unlikely  
ions in  
position  
he two  
e way.  
metal-  
se two  
rstood,  
ial will  
ses the

appre-  
vbegin,  
mental  
ributed  
ents as

Crack  
et Steels  
5127, 9

ck Prop-  
a Sheet

Gases in  
h Sheet  
st 1958,

Surface  
83, 4-9

## Abstract

Results are given of laboratory experiments and periodic examinations on board ship to determine the service behavior of aluminum alloys in wooden hull minesweepers constructed with aluminum alloy frames.

Service failures are illustrated. Most of them were caused by use of incorrect materials, substitution of materials not given in specifications, poor industrial manufacturing or insufficient technical control.

Service behavior of stainless steel used in conjunction with aluminum was good if the surface area ratio of the two materials was about 1 to 5. Zinc chromate as a corrosion inhibitor for aluminum alloys gave satisfactory service.

Other topics included are lagging with asbestos, aluminum corrosion products and use of greases and lubricants containing graphite. 6.4.2

## Introduction

OVER TEN years ago, the Royal Canadian Navy decided to design and build a new class of non-magnetic minesweepers constructed of wooden hulls on aluminum frames with all deck-houses and many internal fittings fabricated of aluminum. These Bay Class minesweepers were diesel powered with fresh and salt cooling waters circulated through aluminum alloy tubes.

The designers found that information on aluminum alloy behavior for the operational service required on these ships was not exact and often contradictory.

Because no prototype ship was to be built, it was decided that all ships of the first squadron should be examined regularly during the first years of service for the overall behavior of the aluminum. This examination was not to be confined to corrosion although corrosion probably would be one of the major factors to be assessed. It was decided also that two laboratory experiments should be instituted, complementary to the eventual shipboard examinations.

In one laboratory experiment a structure was built to approximate conditions in the hull construction of the minesweepers. The main object was to study the corrosion behavior of the fastenings used to bolt the outer wooden planking to the inner aluminum frames.

The second laboratory experiment was a full scale mock-up of the ship's main engine cooling system. The requirement was to investigate the behavior of aluminum pipes and components in the circulating systems which included copper-base alloys. Not only was the question of possible galvanic action studied but also the then unknown behavior of clad aluminum alloy piping handling water containing copper salts.

Duplication occurred, but its value was far greater than was realized at the time the experiments were projected. This was because in the laboratory experiments extreme care was taken that work and materials conformed to specifications set by the Naval Constructor-in-Chief. This enabled valuable check-backs to be made when inequalities occurred on the operational ships.

## Details of Laboratory Experiments

### Hull Experiment

The requirement of the hull experiment was a survey of the corrosion behavior of

\* Submitted for publication October 20, 1958. A paper presented at a meeting of the Northeast Region Conference, National Association of Corrosion Engineers, Boston, Oct. 6-8, 1958.

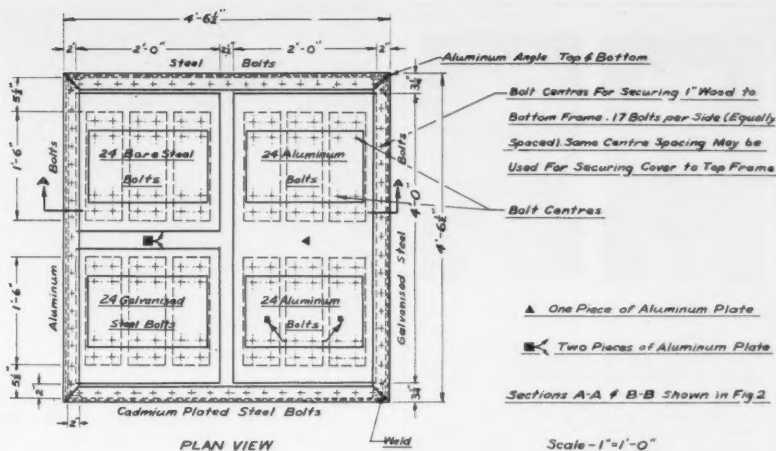


Figure 1—Plan view of box constructed to simulate relationship of aluminum to wood on the minesweepers.

## Uses and Abuses of

# Aluminum in Wooden-Hulled, Aluminum-Frame Minesweepers\*

By T. H. ROGERS and W. K. CHINN

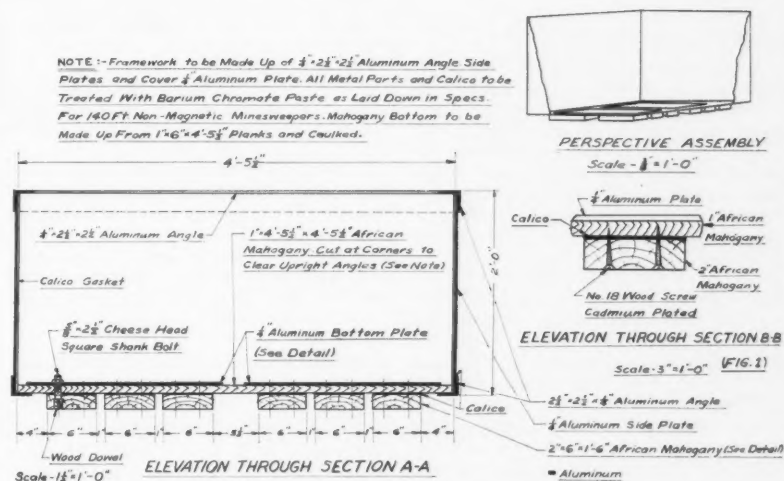


Figure 2—Elevation views of experimental box used in determining service behavior of aluminum as used on wooden hull, aluminum frame ships.

four materials, (aluminum, uncoated steel, galvanized steel and cadmium plated steel) to be used as bolts for fastening wooden skins to aluminum frames of the vessels. Also included in the survey were aluminum screws and clenched nails used to join two layers of the hull planking (African Mahogany).

The experimental construction was a square aluminum (AA6061) box with a mahogany bottom. Each side of the box

was fastened with a different material. Inside the bottom, aluminum plates were used to simulate the frames to which was bolted the wooden skin. Various paint systems were used on different parts of the box and the 2-inch thick outer skin was panelled into several sections so that anti-fouling paint systems could be tested.

Detailed plans and diagrams of the box are given in Figures 1 and 2. Figures 3



Chinn

Rogers

**W. K. CHINN**—Since 1952 has been metallurgist with the Naval Research Establishment, Dockyard Laboratory Section, Defence Research Board of Canada, Halifax, Nova Scotia, where he is engaged in corrosion research relating to HMC ships. Born in Cornwall, England, he was educated at Dolcoath Technical College, has a First Class Foundryman's Certificate from the City and Guilds' Institute of London, England. He came to Canada in 1950 and held supervisory positions in both England and Canada in the ferrous and non-ferrous foundry industries before joining the Defence Research Board.

**T. HOWARD ROGERS**—Officer-in-Charge, Naval Research-Dockyard Laboratory, a section of the Naval Research Establishment, Halifax, N.S. Naval Research-Dockyard Laboratory is the consultative authority on service failures in metallurgy, corrosion, engineering, etc., to the Royal Canadian Navy, Atlantic Command. Before coming to Canada, he was for over ten years in the Corrosion Department of the British Non-Ferrous Metals Research Association, London, England. Mr. Rogers holds a diploma of the Imperial College, London, England and has a Fellowship of the Institution of Metallurgists, London, England and is a member of both the Canadian Aeronautical Institute and ASM.

and 4 are photographs of the inside and outside.

#### Cooling System Experiment

Arrangement of the cooling system experiment is shown diagrammatically in Figure 5. General layout of the plant, shown in Figure 6, was as follows:

The sea water was taken from the harbor directly into a mahogany coffer dam. Because the dam was of the same material as the minesweeper hulls, operating conditions for the aluminum scoops were simulated.

The sea water suction line was run 30 feet from the jetty on the harbor bed to decrease the risk of having contaminated water entering the system. From the coffer dam, the sea water flowed through an 18/8 stainless steel strainer fitted in an aluminum body (Alloy-220) to the main engine circulating pump. After passing through the pump, the water diverged to two copper-base alloy coolers.

The copper-base components were, as far as possible, prevented from contact with the aluminum fittings by means of rubber insulators. The fresh water, heated with controlled temperature was circulated by an auxiliary pump. The water was chromated to 3000 ppm at pH 7.0 and tested weekly for chromate and chloride content. Five temperature control points were located throughout the system. Regular records were kept.<sup>(1)</sup> The

<sup>(1)</sup> These records show that the maximum temperature variation on the hot water lines did not exceed  $\pm 10^\circ \text{F}$ . from the optimum operational temperature. The temperature of the sea water, however, varied from 75 F to 32 F.

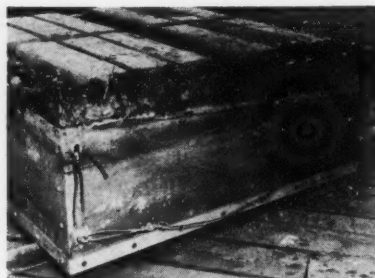


Figure 3—Exterior view of box used to conduct experiments.

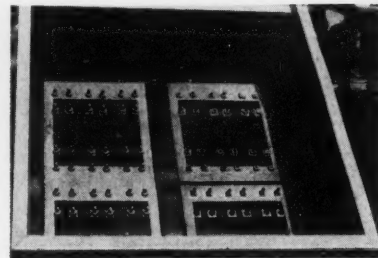


Figure 4—Interior of box showing aluminum plates used in experiments to simulate aluminum frames used in the wooden hull ships.

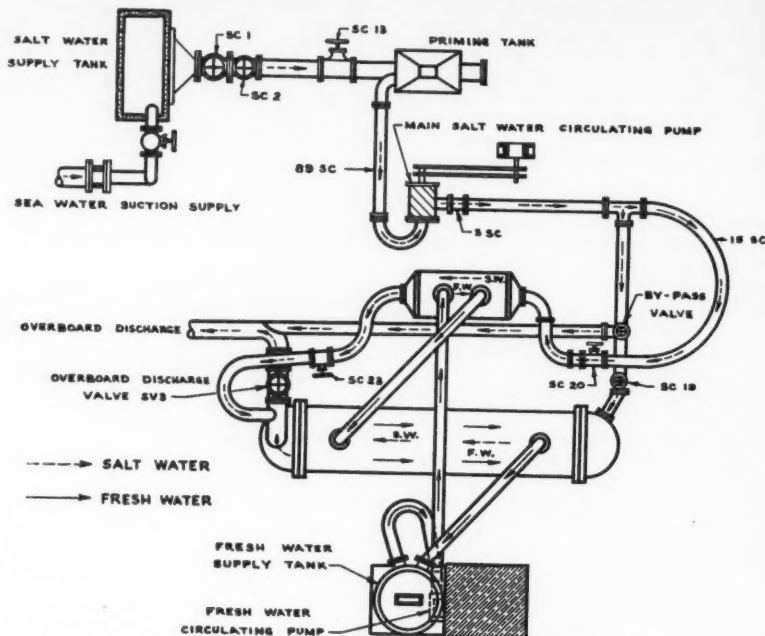


Figure 5—Diagram of the experiment conducted to test service behavior of materials in the minesweepers' cooling system.

plant was run continuously at full speed for the first 2000 hours (passing approximately 28,250,000 gallons) followed by roughly 3000 hours at half speed with frequent shut downs (stagnant periods). Throughout the test period, valve fittings were worked frequently and well lubricated with ordinary lubricating oil.

#### Results From Laboratory Controlled Experiments

##### Hull

**Anti-Corrosive Coatings:** All outside surfaces of the box were coated originally with one or two coats of zinc chromate paint (each coat approximately 2 mils thick) after treatment with a wash primer (WP.1-MIL-G-15328A). Examinations were made after 18 months and 3 years. After the 18-month examination, the zinc chromate coats were wire brushed to remove salt and incipient weed fouling and repainted. The behavior of the zinc chromate was excellent.

At the end of 3 years, no aluminum surface coated with zinc chromate showed corrosion of the underlying metal (Alloy AA 6061) other than superficial attack at scratches. If properly applied,

the surface was a successful barrier to galvanic attack.

Zinc chromate is easy to apply. The metal surface need not receive pre-treatment other than that it be clean and grease free. It can be sprayed or brushed as desired. No other barrier coat has been so successful.

Two coatings were used over the zinc chromate: aluminum paint (pure phenolic vehicle) and standard copper-base anti-fouling paint (alkaline bituminous cuprous oxide). The coats of aluminum paint (approximately 1.5 mil each) over the zinc chromate on the box's exterior did not adhere well, but on the box's interior, when used without zinc chromate, the paint showed little sign of flaking and prevented corrosion in the bilge-like conditions of this location.

Two exterior sides of the box were painted with standard copper-base anti-fouling paints (approximately 1.2 mil each coat); one side was painted over one coat of zinc chromate followed by one coat of aluminum paint, the other side over two coats of zinc chromate. In both cases, some of the anti-fouling paint had stripped from the under-coatings, but the stripping was more severe on the side



having aluminum paint over the zinc chromate, where the stripping occurred mostly between the aluminum paint and zinc chromate.

Copper-base anti-fouling paints had not caused serious acceleration of corrosion of the underlying aluminum. There was more corrosion of the aluminum at scratches on the sides having the anti-fouling paint, but in no case was corrosion more serious than that which occurred on all sides for about 3 inches from the bottom of the box where there had been fouling with weed and mussels.

Severity of incipient corrosion at the scratches bore a direct relation to the width of the scratch, but even inch wide scores appeared to obtain some protection from the zinc chromate, and corrosive attack was negligible. Copper-base anti-fouling paint used on the wooden bottom did not cause any corrosion of the dowelled-in bolts. On the inside of the box, there was only a little corrosion of the unpainted sides or at holidays in the aluminum paint which was sprayed directly onto the aluminum. These findings have been confirmed on the operational ships.

**Fastenings:** Three-eighth inch bolts were used on all sides of the box to fasten the aluminum angles (AA 6061) to the aluminum sheet sides (AA 6061) and on the bottom to fasten the inner 1-inch mahogany planking to the aluminum angles. These bolts were of the following materials: aluminum (AA 6061), mild steel, (AISI-1020) galvanized mild steel and cadmium plated mild steel. One material was used on each side.

All the aluminum bolts, whether fastening aluminum to aluminum or aluminum to wood, showed little corrosion though there was evidence of more attack where these bolts were in contact with the mahogany. At the end of 18 months, those bolts which fastened aluminum to aluminum were tight, but all those bolting aluminum to wood were loose. This was no fault of the aluminum but was an interesting observation which was of value to the operational ships.

Mild steel bolts showed rusting on the heads, inside and outside the box, especially where the protective paint had been removed. Also there was rusting of the bolt threads which projected above the nuts on the inside of the box. In no case was there any evidence of preferential galvanic attack on either steel bolts or aluminum. The bolts were all tight and there was no attack on shanks or threads where they ran through the mahogany. Although corrosion of these mild steel bolts had occurred, the amount of attack found after 3 years was insufficient to condemn them as a fastening; they appeared good for many years of service, especially since no corrosion had occurred under the nuts or on the shanks which were well coated with zinc chromate paste.

Hot dipped galvanized steel bolts (galvanizing 2 to 2.5 mils) under the conditions of the experiment appeared to be the best of the three steel bolts.

Cadmium plated (about 0.3 mils thickness) steel bolts also behaved well, but

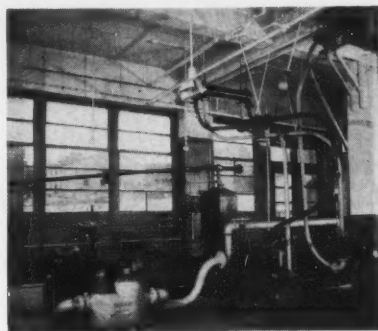


Figure 6—Photo of the cooling system experiment.

on the whole the galvanized steel behaved better. All the cadmium plating was gone at the end of the 18 months. In this experiment there was no attempt to assess the behavior of bolts coated with comparative thicknesses of zinc and cadmium. The requirement was to assess commercial stocks of these components.

Five-eighth inch bolts were used to fasten the wooden planking to the aluminum frames (AA 6061). In the hull experiment, test bolts went through both 2-inch and 1-inch planking. All the bolts were dowelled into the outer 2-inch skin, fitted through holes drilled in the 1-inch wood and fastened to the inside aluminum plates (representing the frames of the ship) with nuts of the same material as the bolts. Before fitting, all bolts were coated with a lubricant and the heads and nuts with Barium<sup>(2)</sup> chromate paste. All dowel holes were filled with black plastic cement.

Examination of the bolts of all three materials showed no significant corrosion of heads, shanks or those portions of the threads embedded in the mahogany. The only bolts to show any corrosion at all in these positions were the aluminum, which in some cases showed attack on the shank, evidently caused by the mahogany and not by any leaching inwards of the copper-base anti-fouling paints. In general, all aluminum components showed evidence of slight attack if they were touching the mahogany without a barrier coating. In the bilge, projecting threads of the aluminum under the nuts showed little attack. In all cases, there was slightly more attack of the aluminum where it was in contact with the mahogany. However, rate of attack was negligible because conditions in the inside (bilge) of the box were severe (alternately wet and dry) over a period of 1½ years.

Galvanized steel bolts showed good resistance to the bilge conditions. There was no corrosion of nuts or threads, and there was no preferential attack of the aluminum to which they were bolted. Behavior of aluminum bolts in the operational ships was not as satisfactory. In view of the hull experiment results, the trouble on the ships was considered to be caused by insufficient coatings of zinc chromate.

<sup>(2)</sup> There was no appreciable difference between the barium chromate paste and the zinc chromate paste. The reason zinc has been preferred is purely economic.

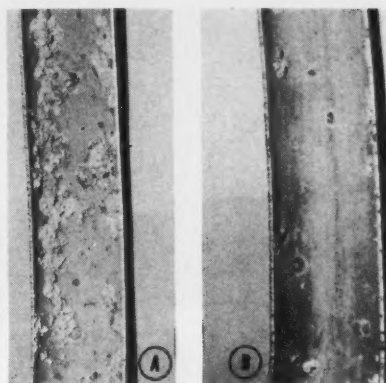


Figure 7—Cross sections of clad aluminum tubing used in minesweeper cooling system. Section A was located 3 feet from copper-base main circulating pump; Section B was 10 feet from pump. No complete penetration was found, but the attack was heaviest near the copper-base alloys.

Steel bolt nuts had rusted, and there was galvanic attack of the aluminum around the steel nuts. The amount of attack, however, though more pronounced than that found with the other two materials, was not sufficient to condemn this material, under the conditions of test.

The clenched nails (AA 5056) showed no corrosion. This was confirmed by their service in the operational ships.

Many of the aluminum screws (AA 6061) showed severe pitting where the shank joined the threads. Some had corrosion at the tips. The reason for this is not known, but this corrosion was not caused by seepage of copper containing salt water down the shanks because the same type attack was found on the screws drawn from the copper-base and the non-copper-base anti-fouling paint sections.

It is understood that these screws are cut, not "rolled" in manufacture; therefore, a stress concentration may have occurred at the point of entry of the tool. The corrosion of the tips was due possibly to work hardening, this time caused by the driving of the screw, placing all the work on the tip.

The same type of attack was found in the operational ships, and it would appear that the aluminum screws (AA 6061) are not satisfactory for use in these conditions.

The cadmium plated (approximately 0.3 mil screws showed no serious rusting although the heads lost some plating. They have not been used operationally because of expense.

#### Cooling System Experiment

Generally, the cooling system was in good condition, suggesting that the system is satisfactory when the specifications set by the Naval Constructor-in-Chief are followed. Where the clad aluminum tubing (AA 3003 clad with AA 7072) was downstream of the copper-base fittings, the piping corroded in many cases to the depth of the cladding but never showed complete penetration. The sections of tubing which were cut showed that the attack was heaviest near the copper-base alloys (G. Bronze) and decreased rapidly the further the piping was from these components. At 6 feet

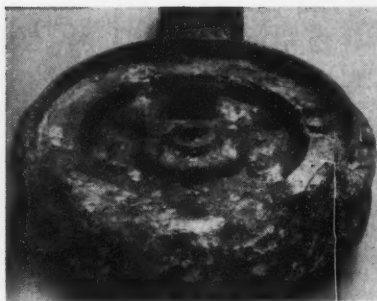


Figure 8—Corroded valve of the wedge pattern. Failure was attributed to galvanic attack caused by the unfavorable ratio of aluminum to stainless steel used in the valves. Stainless steel side plates are not shown.

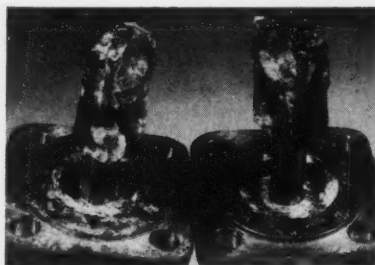


Figure 9—Corrosion of wedge valve with aluminum chairs. Stainless steel inserts are not shown.

failure was caused by a combination of circumstances.

*Use of incorrect materials and non-compliance with original specifications.*

These fell under three headings. (1) Substitution, due to non-availability of specified material at time of building. (2) Substitution of unspecified material by shipbuilders for various reasons. (3) Specifications of incorrect material made in good faith by the designers because of limited knowledge of service behavior.

**Aluminum Tubing.** The use of clad tubing, (AA 3003 clad AA 7072) has been successful and no case has been found to date in the ships or the shore based experiment where tubing of this type suffered penetration. In some ships, this tubing has 8 years operational life with possible satisfactory service for 10 years or more. Unclad AA 5052 alloy tube, however, in the salt water cooling systems on the main engine and in the salt water flushing lines to the sanitary facilities, was not satisfactory. The AA 5052 lines to the salt water cooled air compressors corroded badly in all the ships examined, replacement has been necessary. In many cases where this alloy failed, it had been fitted in lieu of the clad material.

As a result of the tests, two suggestions were made. (1) If clad alloy is not available in the small sized tubing, systems requiring small sizes such as the air compressor cooling systems should be altered to the use of chromated fresh water or more plastics should be used. (2) Because substitution of non-clad alloy for clad alloy was due in many instances to the shipbuilders' inability to distinguish between the two types of material, all aluminum alloy tubing should be marked with alloy numbers before delivery to shipyards or dockyards.

As a result of the shore based and operational experiments, the Naval Research-Dockyard Laboratory decided that all tubing carrying fresh or salt water should be in clad alloy. AA 5052 tubing can be used satisfactorily with fresh water, but the use of the two alloys in ships for similar systems will lead to confusion and incorrect use during construction and at future refits.

**Valves.** Examination of globe type valves with bodies to Specifications 356 and 220 revealed that two methods of manufacture were in general use: (1) Disc, spindle and seat of 18/8 stainless steel; body of aluminum. (2) Disc and

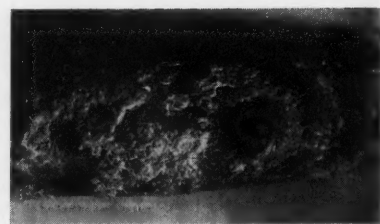


Figure 10—Asbestos lagging around aluminum pipe caused rapid failure by penetration from the outside where the asbestos was wet by sea water.

spindle of 18/8 stainless steel; seat and body of aluminum.

If the seating was aluminum, seat failures by corrosion in most instances was complete. If the working unit was completely stainless steel, the valves were in excellent condition. Therefore, working units always should be stainless steel; bi-metallic construction should not be used.

Gate valves examined also were the aluminum/stainless steel type. Failure or breakdown of the valve gates, which were bi-metallic, also was complete, as shown in Figures 8 and 9. This condition probably was caused by the unfavorable ratio of aluminum to stainless steel. Service life of this valve type was very short.

Gates in these valves were of two different constructions; the cause of the serious corrosion was common to both. In one type, the aluminum chair had an inserted stainless steel disc; in the other, the aluminum chair had stainless steel side plates. In each case, cause of corrosion was the large area of cathodic stainless steel to the small area of anodic aluminum. Although to suggest specific area ratios is difficult because of the variable conditions found in practice, the ratio of aluminum to stainless steel is tentatively recommended at never less than five to one.

These valves were usually operated in the half to fully open position. This may have contributed to the excessive corrosion found, but the main failure cause was assumed to be galvanic action and not corrosion/erosion. This galvanic action often was doubly serious because the aluminum corrosion products are so voluminous, and in consequence, the valves often became inoperative due to plugging and seizure of the internal mechanism. When those valves with aluminum chairs were failing, some corroded valves were removed from the ships and re-worked with stainless steel chairs. These re-worked valves have given good service for over 3 years.

**Lagging.** Another instance of the use of materials not to specification was asbestos lagging around aluminum heating lines exposed to wind and weather. Fibreglas was specified, and in ships so fitted no corrosion had taken place. In three shops on which the lagging was asbestos, rapid failures occurred by penetration of the aluminum pipe from the outside due to the leaching of alkali from the asbestos. (Figure 10).

**Ferrules.** There was considerable corrosion of aluminum ferrules (AA 6061) at localized positions where the piping

or more from the leaching copper, the corrosion film was even and the cladding practically unattacked. (See Figure 7).

The aluminum alloy valves (220 and 356) examined were all in good condition. No seizing was evident and the spindles could be easily turned.

The valve seatings, face plates and spindles also were in excellent condition. Valve flange faces were in good condition, except one end of the overboard discharge valve which was not fitted with an insulator, which was badly attacked by galvanic action where it was in contact with the large copper-base fresh water cooler. Other aluminum components throughout the system such as elbows and tee pieces (356) were in good condition with only a slight corrosion film present.

The copper-base fittings such as the cross pieces and adaptors had an even corrosion film and were in excellent condition.

When valves with stainless steel (Type 304) working parts, as fitted in the experimental system, were lubricated frequently and the spindles worked at regular intervals, there was no evidence of seizing. The corrosion film which formed on the face plates and slides did not affect valve operation.

In the operational ships, behavior of the aluminum valve spindles sometimes was not good. This was due to two causes: (1) some valves once set are rarely altered, thus, the spindles are not worked, and (2) the use of graphitic greases.

The aluminum tubing (AA 5052) on the fresh water service lines was in excellent condition indicating that, if the correct chromate concentration is used, tubing life probably will be almost indefinite, providing that no other conditions such as galvanic couples are present.

Aluminum valve bodies were not attacked and were in excellent condition except for a slight film of corrosion product. Some valve bodies were rough inside; this condition, however, was due to roughly finished sand castings, not the effect of sea water.

#### Examination of the Operational Ships

Examinations revealed that, on the whole, the failures can be classified in certain broad categories. The order in which they are listed below is of no special significance. Sometimes, of course, a



was jointed as shown in Figure 11. Generally, when used to join aluminum pipe to aluminum pipe, aluminum ferrules were in good condition. However, ferrules at joints close to copper-base components failed sooner than those in the same line further down stream from the leaching copper.

In the salt water cooling lines to the general service pumps, however, where copper piping was joined to an aluminum component, severe corrosion of the aluminum ferrules occurred. The reason was that the aluminum ferrule was a small anode in contact with a large cathode. Use of isolated ferrules is recommended, or preferably, the fitting of flexible joints of wire wrapped rubber when connecting non-ferrous piping to aluminum piping in salt water systems.

**Greases.** When the ships came from the shipbuilders, a considerable quantity of graphite containing greases were found as lubricants on valves, deck fittings, plugs, etc. Considerable corrosion and seizing soon took place.

The problem of the seizure of valve spindles, etc., is more serious if bearing surfaces are aluminum-to-aluminum or stainless steel-to-aluminum rather than conventional bearing surfaces. This is because the aluminum corrosion products are voluminous and tend to adhere to the bearing surface. For this reason, it is most important that greases used should not be corrosive. Trials of five lubricants and greases were initiated: proprietary dry lubricant compound, proprietary wet lubricant compound, Alcoa Threadlube, Parker Threadlube grade 6B and a mixture of 50 percent zinc dust and 50 percent vaseline by volume.

Examinations were made at three-month intervals. The first examination indicated that the dry compound on the plug valves in the fuel oil system was not adhering to the plugs during the passage of fuel oil. The wet compound performed well on the threads and spindles. The three greases gave excellent service on the threaded positions of deck fittings, engine room valves and spindles.

After six months, examination showed the Alcoa, Parker and zinc-vaseline greases to be superior in quality for anti-seizure and corrosion prevention.

In the presence of sea water, greases containing graphite can be a menace. Shipbuilders should be warned against their general use. The use of graphite should be avoided in any form where aluminum is in contact with sea water. For instance, shipbuilders' instructions should not be pencilled on bare, unpainted aluminum because the couple between the graphite and the aluminum causes the instructions to be etched permanently into the surface.

**Zinc Protector Blocks.** Sacrificial zincs fitted to the various copper-base coolers behaved differently in service. Those supplied with the original coolers did not corrode in the manner required, the area actually sacrificed was often very small or negligible. The inequalities in the behavior of these sacrificial anodes is considered to be caused by the zinc compo-

sition. Recent research has shown that for the successful operation of zinc sacrificial anodes the iron content must be limited to 0.0014 maximum. Zinc of such purity, or equivalent quality was satisfactory. Zinc of low iron content is recommended.

**Deck Fittings, Hose Nozzles, Deck Sockets.** Failures of deck fittings such as flush fitting threaded deck sockets on fuel and domestic lines were prone to corrosion with ultimate seizure of the component sometimes making removal impossible. Most failures were traced to the use of graphite based lubricants. The use of greases not containing graphite has reduced this type of failure to negligible proportions.

Other failures were due to the coupling of bronze fire nozzles to aluminum hose fittings on the fire-fighting and damage control systems. The threaded aluminum component on the fire hose, when screwed into the copper-base nozzle, disintegrated because of galvanic action between the two metals. This problem might be solved by making the nozzles of an aluminum alloy. Experimental aluminum nozzles, however, proved to be unsatisfactory in marine environments because of the formation of corrosion products which jammed the working parts.

#### Component Design

**Swing-Over Plug Valves.** After approximately three months operation, aluminum plug valves (356) on the fuel strainers were found liable to seize with occasional breakage of the spindles. In some cases the valves became so badly scored that they could not be closed. Laboratory examination showed the cause of the trouble was the incorrect angle of taper of the plug.

Another instance of taper and seizing difficulties was experienced on the aluminum (356) Y fire-main deck fittings.

**Guard Rail Wires.** Aluminum (AA 5052) guard rail wires were subject to frequent breakages. Investigation led to the conclusion that the cause in many cases was due to localized corrosion of the individual strands with consequent reduction of flexibility. At some locations, especially gangway openings and stern rails, many failures were caused by heavy handling by personnel who did not realize that aluminum wire would not withstand rough usage often given to steel cable. Complaints were received from ships' staffs of the danger to clothes and hands when the strands of these wires broke, but most of these complaints came from breaks where the wires were continually handled and bent out of the way instead of being removed.

Some investigation was initiated into improving the service of these wires. A series of experiments undertaken with new types of wire, both bare and plastic cased, showed the plastic covered material to be so satisfactory that nothing else is used now on these ships.

#### Manufacture of Components

**Covers—Sanitary Pumps.** The material (220) of the sanitary pumps which sup-



Figure 11—Corrosion of aluminum ferrules.

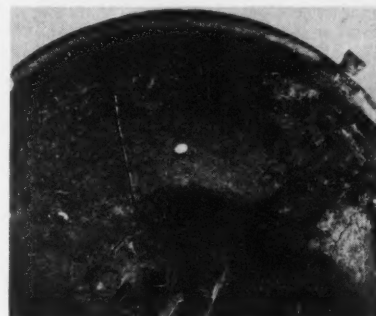


Figure 12—Stress corrosion failure of sanitary pump cover made of aluminum alloy 220. Amount of magnesium in this alloy was considered critical.

ply sea water to the sanitary systems (one pump per ship) has not been satisfactory. Of seven pumps examined to date, cover failures (Figure 12) were found in three and body lug failures in one. In all cases but one, percentage of Mg was above the specified limits. Cause of these failures was thought to be stress corrosion. Investigation undertaken in conjunction with the Aluminum Company of Canada suggests that the amount of magnesium in this alloy is somewhat critical.

Metallurgical and radiographic examinations also revealed that there were other inequalities besides corrosion such as porous and dirty castings, and in some components, heat treatment after casting had been incorrect or inadequate. If this material is used in marine locations, the magnesium content should be between 9.5 and 10.5 as required by Alcan Specifications. Care should be taken in casting techniques with regard to runners, sand, pouring temperature and heat treatment.

**Stanchions and Stanchion Sockets.** Many cast (220) aluminum stanchions and stanchion sockets failed in service. Failure examples are shown in Figures 13 and 14. Some failed due to stress corrosion, but some showed casting cracks which had been present before the stanchions were put into use. Non-destructive examination revealed that some stanchions which had cracked had been repaired by welding. The use of forged guard rail stanchions is recommended in locations where a fracture would endanger personnel. This avoids any chance of weak stanchions due to welded repairs to 220 alloy.

**Storm Valve Covers.** A case was found



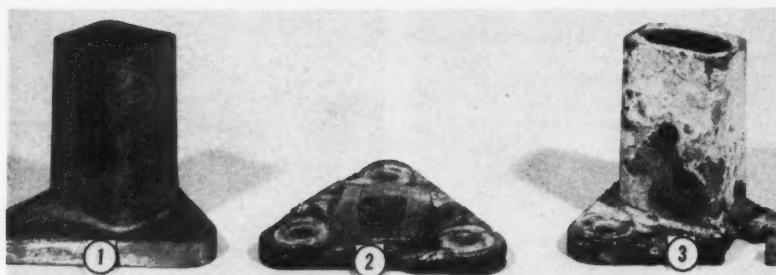


Figure 13—Stanchion sockets made of aluminum alloy 220. Number 1 is a new socket; Numbers 2 and 3 are failed components.

where a storm valve cover, also made of 220 alloy, cracked. This failure was particularly interesting because the component was entirely unstressed in service. The failure apparently was caused by incorrect heat treatment.

**Door Dogs, Rope Wheel Handles and Gangway Gate Hinges.** There were many failures of door dogs and clips to watertight bulkheads, gangway gate hinges and rope wheel handles. Chemical analysis and radiographic examination revealed that these components often were not to specification and that casting quality was not satisfactory.

Samples of the sand castings were examined and found to be extremely porous, cracking was prevalent and there was excessive shrinkage. Although the drawings specified 220 alloy, many cases were found where the composition of the material was not to specification.

These small castings were extremely unsatisfactory in every respect for the services intended. Stricter technical control is required for these small and seemingly unimportant components. Scrap should not be used, and there should be adequate inspection of the finished product.

After service performance of these small 220 aluminum castings was investigated in conjunction with the Aluminum Company of Canada, it was decided that 220 alloy was not suitable for the operational requirement. For replacements and in future ships of the class, it was agreed that, in spite of the lower mechanical properties, alloy 356 should be used.

**Miscellaneous Examinations.** Several instances were found of corrosion of aluminum tubing associated with rubber isolators, shown in Figure 15. These troubles occurred mainly in two locations: small bore tubing on salt water systems and large flanged isolators on sea water systems.

Throughout the salt water cooling systems there were various places where short lengths of rubber hose were inserted in the lines. These pieces were from six inches to one foot long and overlapped the metal pipe at each end approximately 1 to 1½ inches. In some cases, they were in all aluminum lines; in others, one end was on a copper tube and the other end on an aluminum tube. Beneath these rubber hose insulators the aluminum tubing ends were corroded

severely. Not only was the corrosion sufficiently serious to cause failure, but also the corrosion products caused the pipes to become blocked.

Where the isolators joined tubing of different metals, corrosion on the aluminum was undoubtedly galvanic, the circuit being completed because, contrary to specifications, these pipes were grounded on both sides of the isolator. In the cases where the tubing was all aluminum, the reason for the corrosion which was on the tubing at both isolator ends was not quite so obvious but was considered to be due to grounding to non-isolated frames. It also may have been due to crevice attack caused by fitting the clips too far from the rubber tubing end.

Where large flanged isolators on salt water systems joined aluminum and copper components, ends of the aluminum fittings suffered corrosion. This failure was not general throughout the ship but occurred only at certain localities. Electrical surveys around the general areas of these particular failures indicated that these isolators were not truly isolated. This condition probably was caused by the strap hangers between the frame members and the piping or valve fittings not being insulated from ground. In effect, the system was shorted, allowing continuous electrolytic action with consequent corrosion of the aluminum.

The wooden hull planks were bolted to the internal aluminum frames with aluminum bolts (AA 6061). Because these bolts were exposed to wood wet with sea water and a check on their corrosion behavior necessary, regular withdrawals were made on suitable occasions during the first two years of the operational life of these ships. The results were quite clear: the bolts did not corrode if the specified chromate paste treatment was used by the shipbuilder. Unfortunately, the time consuming and dirty operation of dipping the bolts in zinc chromate paste was not always carried out, and the uncoated bolts showed corrosion.

**Overall Behavior of Aluminum and Aluminum Alloys.** These experiments have shown that of many different alloys and types specified, the overall behavior of the correct materials has been as good and often better than expected. Defects only occasionally have been due to the use of aluminum but have, almost in every instance, stemmed from insufficient

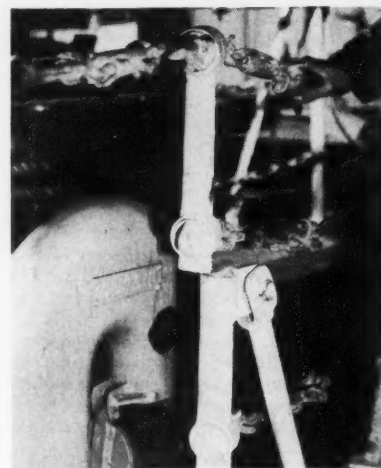


Figure 14—Failure of cast aluminum stanchion.



Figure 15—Corrosion of aluminum pipe at rubber isolator.

know-how, inadequate inspection or the use of unspecified materials.

#### Education in the Use of Aluminum

The authors feel very strongly that all along the line there has been insufficient attention called to the difference between the use and behavior of the new light alloys in comparison with steel. This is particularly apparent in the operational ships. There is definitely insufficient appreciation among ships' companies that they are operating a new type of ship, not only tactically and operationally but also mechanically. Aluminum, no matter how successful as a light substitute for steel, does, indeed, need more delicate handling.

#### Acknowledgments

The value of the examinations and experiments conducted to the requirements of the Engineer-in-Chief and Naval Constructor-in-Chief of Royal Canadian Naval Headquarters has been enhanced by the co-operation of the Squadron Engineers, Heads of Departments under Commodore Superintendent Atlantic Coast, and the Technical Officers on the staff of Flag Officer Atlantic Coast. We especially mention Mr. R. Judge, who co-ordinated the effort.

The authors acknowledge permission of the Defence Research Board and the Royal Canadian Navy to publish this paper. Thanks are due to numerous staff members of the Dockyard Laboratory Section and the Physical Chemistry Section of Naval Research Establishment for many helpful services.

# Zinc in Marine Environments\*

By E. A. ANDERSON

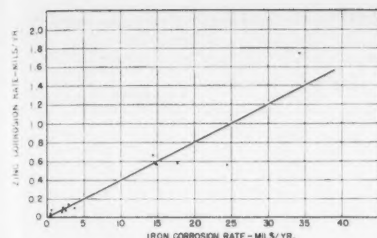


Figure 1—Comparison between corrosion rates of iron and zinc.

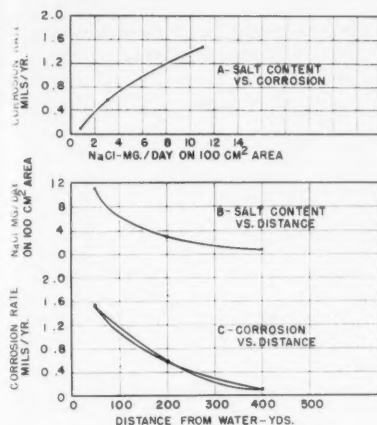


Figure 2—Corrosion rate of zinc vs. distance from shore and salt content of air.

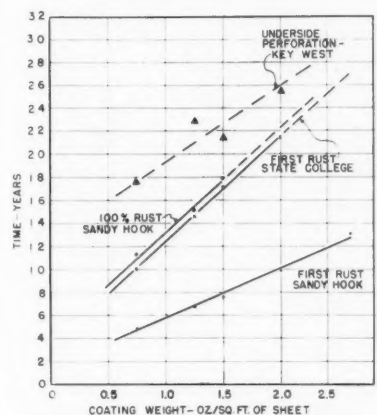


Figure 3—Time to failure vs. coating weight.

TABLE 1—Corrosion Penetration of Zinc in Marine Locations

Location	Type Atmosphere	Penetration (mpy)	
		Fe	Zn
Brixham, England	English Marine	2.1	0.07
Calshot, England	English Marine	3.1	0.14
Khartoum, Sudan	Dry Tropical	0.1	0.02
Singapore, Malaya	Marine Tropical	0.6	0.04
Apapa, Nigeria	Marine Tropical	1.1	0.05
Congella, Durban*	Marine Industrial	4.5	0.19
Lighthouse Beach, Lagos, Nigeria	Marine Beach	24.4	0.56

\* Union of South Africa.

SEASHORE ENVIRONMENT<sup>1</sup> variables may influence the corrosion rate of a metal. Included are the distance from the ocean, amount of rainfall, prevailing relative humidity, ambient temperature range, frequency and extent of cloudiness and amount of industrial gas contamination in the air. All these affect the rate at which zinc corrodes.

An example of seashore environmental variables affecting corrosion rates is given below: In Nigeria the salt content of the atmosphere decreases somewhat linearly with distance from about 12 mg/m<sup>3</sup> at the mean high water line to about 0.2 mg/m<sup>3</sup> ten miles inland<sup>1</sup>. These readings apparently were taken at ground level. Values were noted of 5.0<sup>2</sup> at a 75-foot elevation and 0.8 at ground level at a position 400 yards from the high water point.

Data in Table 1 are for a variety of marine locations based on one-year exposure. Specimens were of 4 by 2 by 0.020-inch rolled zinc vertically exposed and chemically cleansed of corrosion products after completion of the test. Similar tests on mild steel are included for comparison.<sup>2</sup>

The effect of distance from the water at a single location (Lighthouse Beach, Lagos) is given in Table 2. Separate tests were made during the wet season, dry season and over the entire year.<sup>2</sup> The effect of distance from the water on corrosion rate is given in Table 3.<sup>1</sup>

In ASTM tests, three grades of rolled zinc were exposed for 20 years at each of seven marine locations.<sup>3,4</sup> The seacoast locations were at Key West, Florida; Sandy Hook, New Jersey and La Jolla, California. For comparison, data from the rural inland exposure at State College, Pa., are included.

These tests were made on 9 by 12-inch panels exposed vertically. Weight loss

★ Submitted for publication December 1, 1958. A paper presented at a meeting of the Northeast Region Conference, National Association of Corrosion Engineers, October 6-8, 1958, Boston, Mass.

TABLE 2—Effect of Distance from High Water Mark—Lighthouse Beach, Lagos, Nigeria

Distance from Beach (Yards)	Salt in Air*	Penetration (mpy)					
		Fe		Zn		Whole Year	Whole Year
		Wet	Dry	Wet	Dry		
50.....	11.1	45.9	45.0	37.7	1.86	1.48	1.51
200**.....	4.2	13.3	9.0	17.7	0.89	0.78	0.58
200.....	3.1	22.9	3.7	14.9	0.69	0.36	0.57
400***.....	5.0	18.9	11.2	No Data	0.63	1.52	No Data
400.....	0.8	3.9	2.5	2.2	0.27	0.16	0.11
Kure Beach—80 ft.....	...	...	...	...	...	...	0.39
Kure Beach—800 ft.....	...	...	...	...	...	...	0.07

\* Milligrams of NaCl caught per day on 100 cm<sup>2</sup> area of cloth.

\*\* Seventeen feet above ground.

\*\*\* Seventy-five feet above ground—others at ground level.



About the Author

EDMUND A. ANDERSON has been a member of NACE for 13 years, joining in 1945. He is now the NACE corporate member representative of his firm, The New Jersey Zinc Co. of Pennsylvania. He has been in active charge of corrosion work for his firm for 33 years and holds a PhD degree (1920) and an MS degree (1923) from Yale University.

## Abstract

Data from unpublished experiments and the literature are reviewed and analyzed on behavior of zinc in marine atmospheres and in sea water immersion. Includes atmospheric studies of cast and rolled zinc and galvanized iron, sea water immersion tests of zinc and atmospheric and sea water studies of zinc-rich paint. 4.2.5

measurements were made on one duplicate set of panels after a 10-year exposure and on a second set after 20 years. Corrosion products were removed chemically in determining weight losses.

The Key West racks were placed a short distance from the shore and the Sandy Hook racks about 100 yards. At La Jolla, specimens were exposed on a 20-foot bluff 100 yards from the water. The Sandy Hook environment included substantial industrial gas contamination which increased during the test period. Because no significant differences were observed between the three grades of zinc, data for Metal BB (0.049 Pb0.002 Cd-0.019 Fe) only are assembled in Table 4.

Additional data are available from Kure Beach exposure tests on 1 by 4 by

TABLE 3—Distance Effect

Location	Distance	Penetration (mpy)*	
		Fe	Zn
Lighthouse Beach, Nigeria	50 Yards	34.2	1.74
Lighthouse Beach, Nigeria	200 Yards	14.4	0.67
Lighthouse Beach, Nigeria	200 Yards**	0.97	No Data
Lighthouse Beach, Nigeria	400 Yards	7.8	No Data
Fisheries, Nigeria	1,300 Yards	2.0	No Data
Onikan, Nigeria	3,000 Yards	2.4	No Data
Ikoyi, Nigeria	2 Miles	1.6	No Data
Oshedi, Nigeria	10 Miles	1.6	No Data
Port Harcourt, Nigeria***	25 Miles	2.6	0.087
Nkpoku Jungle, Nigeria	30 Miles	0.61	0.094
Llanrhystyd, Wales	300 Yards	6.7	0.28
Hill Village	1 Mile	3.8	0.10

\* Converted from g/dm<sup>2</sup>/mo. of reference.

\*\* Indoors—window open toward sea.

\*\*\* Industrialized atmosphere.

TABLE 4—ASTM Data on Metal BB

Location	Penetration (mpy)	
	10 Yrs.	20 Yrs.
Key West	0.019	0.022
Sandy Hook	0.059	0.073
La Jolla	0.068	0.069
State College	0.040	0.044

TABLE 5—Kure Beach Tests on Iron-Containing Rolled Zinc

Fe-%	Penetration (mpy)			
	80-Foot Rack		800-Foot Rack	
	Six Months	One Year	Six Months	One Year
0.0003	0.4	0.4	0.3	0.2
0.0008	0.45	0.3	0.3	0.2
0.0014	0.5	0.4	0.3	0.2
0.0021	0.5	0.4	0.3	0.2
0.006	0.45	0.4	0.3	0.2
0.011	0.45	0.6*	0.3	0.2

\* 0.2 and 1.0 mil/year on duplicate panels.

1/2-inch specimens of rolled special high grade zinc with iron contents from 0.0003 to 0.011 percent. These specimens were placed on 80-foot and 800-foot racks with separate sets for weight change determination after six-month and one-year tests. Data appear in Table 5.

Ten-year exposure tests of vertical panels have shown (Table 6) that, though alloy and non-alloy zinc corrodes at about the same rate in the New York industrial atmosphere, there are definite effects due to alloying in the marine exposures.<sup>6</sup> The Key West exposure was made at the Sand Key lighthouse some miles away. Distance to the ocean was not recorded but visual evidence of spray corrosion and sand erosion was present. The Montauk Point, Long Island, rack was placed on the edge of a bluff near a lighthouse and probably received spray during storms.

The effects of time and period of the year at which exposures are started have been studied at Kure Beach, North Carolina.<sup>6</sup> Data in Table 7 were obtained on vertically exposed 2 by 4 by 0.054-inch rolled zinc specimens facing east on an 80-foot rack and south on an 800-foot rack. One set was started in March, 1951; the other in January-February, 1953.

TABLE 6—Marine Atmosphere Tests on Zinc and Zinc Alloys

Type Zinc	Penetration (mpy)		
	New York	Key West	Montauk Point
High Grade (a)	0.28	0.14	0.12
Brass Special (b)	0.27	0.14	0.13
1 Cu-0.01 Mg (c)	0.23	0.26	0.16
Zamak-3 (d)	0.22	0.30	0.43

(a) Rolled Zinc—similar to BB in Table 4.

(b) Rolled Zinc—about 0.3 Pb, 0.3 Cd, 0.012 Fe.

(c) Rolled Alloy—High Grade Zinc base.

(d) Die Cast Alloy—4 Al, 0.04 Mg, balance Special High Grade Zinc.

TABLE 7—Effect of Initial Exposure Time

Rack	Corrosion Rate (mpy)*	
	March 1951	Jan-Feb, 1953
80 Feet	0.4	0.2
800 Feet	0.1	0.1

\* Exposed for one year.

Data in Table 8<sup>5</sup> indicate that the corrosion rate of zinc diminishes with time at this location and does not reach its final value until after an exposure of about three years. Tests in triplicate or quadruplicate for each exposure were made with 4 by 6-inch rolled zinc specimens exposed vertically on an 800-foot rack at Kure Beach.

Data on the corrosion rate of zinc as a function of time are given in Table 9.

### Discussion of Tests

With the exception of specimens exposed very close to the ocean, the corrosion rates for zinc are small. Average value for all marine tests is 0.30 mpy. If the decrease in rate with time noted in Table 8 holds for all locations, the average value recorded in Tables 1, 2, 3, 5 and 7 which are based only on a one-year exposure would be reduced by about half. In the United States' general marine environment, corrosion rates of less than 0.1 mpy are to be expected.

The relative behavior of iron and zinc, when plotted against each other as in Figure 1, shows that most points fall on a straight line which places the corrosion rate of iron in marine atmosphere at 25 times that of zinc.

Data on salt content of marine atmospheres and zinc corrosion rate as func-

TABLE 8—Variation in Corrosion Rate With Time

Exposure Period—Months	Corrosion Rate (mpy)
6	0.15
12	0.11
18	0.08
24	0.12
36	0.09
42	0.08
72	0.07
84	0.07
90	0.06
108	0.04
168	0.06
180	0.06
186	0.04

TABLE 9—Variation of Corrosion Rate of Zinc With Time

Location	Time—Months	Corrosion Rate (mpy)*
Lagos** 50 Yards	3	1.3
Lagos - 50 Yards	4	1.9
Lagos - 50 Yards	12	1.5
Lagos - 200 Yards	3	0.36
Lagos - 200 Yards	4	0.67
Lagos - 200 Yards	12	0.62-0.58
Lagos - 200 Yards	13	0.62
Nkpoku	3	0.18
Nkpoku	4	0.074-0.11
Nkpoku	12	0.023-0.015-0.027

\* Converted from g/dm<sup>2</sup> values in reference.

\*\* Nigeria.

tions of distance from the water are plotted in Figure 2.<sup>3</sup> In Curve A the salt content is plotted against corrosion rate. In Curve C two different parabolic curves are drawn through the three points.

From these curves the conclusion can be made that there is a direct relation between atmospheric salt content and corrosion rate of zinc. Curve A, however, reveals that the curve is approaching zero corrosion rate at zero salt content which, of course, cannot be.

Evidence indicates that zinc is responsive to the extent and duration of dewfall which would be expected to decrease from the water's edge toward the inland. Variations in frequency and duration of moisture contact with distance possibly play a larger part in determining the corrosion rate of zinc than does salt content. The greater corrosion rate at La Jolla is believed to be caused by higher relative humidity and greater dewfall.

### Galvanized Steel

Other A.S.T.M. tests on galvanized and black iron corrugated sheets<sup>7</sup> are useful in the present context because, with the exception of La Jolla, the same exposure sites were used for rolled zinc and galvanized sheet. Data after a 32-year exposure are compiled in Table 10.

Although the failure rate of the exposed upper zinc coating is very low at Key West, the sheets failed by perforation due to corrosion from the underside. Perforations tended to locate in the crests of the corrugations over the lower purlin support of the exposure rack. This type failure occurred at no other test location.

Causes of this abnormal corrosion have not been determined completely, but a



TABLE 10—Atmospheric Corrosion of Corrugated Galvanized Sheets

Location	Steel Gauge	Weight of Coating (a)	Time in Years To—				
			First Rust	100% Rust	Sheet Perforation	Rust (b) Spots	Perforation from Below (b)
Key West.....	22	None	.....	.....	3.9	.....	.....
Key West.....	16	2.5	> 32	> 32	> 32	> 32	21.9-> 32
Key West.....	22	2.5	> 32	> 32	> 32	25.5	24.3-> 32
Key West.....	22	2.0	> 32	> 32	> 32	22.8	25.5
Key West.....	22	1.5	> 32	> 32	> 32	19.8	21.5
Key West.....	22	1.25	21.5-> 32(c)	> 32	> 32	19.8	22.8
Key West.....	22	0.75	18.3(d)	> 32	> 32	12.5(d)	17.5(d)
Key West.....	28	0.75	18.7(d)	> 32	> 32	13.1(d)	18.9(d)
Sandy Hook.....	22	None	.....	.....	7.3(d)	(e)	(e)
Sandy Hook.....	16	2.5	11.8	> 32	> 32	(e)	(e)
Sandy Hook.....	22	2.5	13.1	> 32	> 32	(e)	(e)
Sandy Hook.....	22	2.0	9.9	> 32	> 32	(e)	(e)
Sandy Hook.....	22	1.5	7.6	17.9	> 32	(e)	(e)
Sandy Hook.....	22	1.25	6.8	15.2	> 32	(e)	(e)
Sandy Hook.....	22	0.75	4.8	11.3	> 32	(e)	(e)
Sandy Hook.....	28	0.75	4.9	11.1	> 32	.....	.....
State College.....	22	None	.....	.....	26	(e)	(e)
State College.....	16	2.5	24.6	> 32	> 32	(e)	(e)
State College.....	22	2.5	26.3(d)	> 32	> 32	(e)	(e)
State College.....	22	2.0	22.5	> 32	> 32	(e)	(e)
State College.....	22	1.5	17.1	> 32	> 32	(e)	(e)
State College.....	22	1.25	14.6	> 32	> 32	(e)	(e)
State College.....	22	0.75	10.0	23.5	> 32	(e)	(e)
State College.....	28	0.75	11.1	24.0	> 32	(e)	(e)

(a) In ounces per square foot of sheet coated both side.

(b) Rust spots and perforation due to corrosion from below penetration zinc coating on upper side.

(c) Only one sheet showed first rusting—remaining 16 showed no rust in 32 years.

(d) Average of sheets showing failure—final average may be higher.

(e) Corrosion from below did not occur at this site.

TABLE 11—Calculated and Observed Coating Life

Location	Weight of Coating (a)	Time to 100% Rust—Years		Time to Perforation of Black Iron—Years
		Observed	Calculated	
Key West.....	2.5	> 32	99	..
Key West.....	2.0	> 32	79	..
Key West.....	1.5	> 32	60	..
Key West.....	1.25	> 32	50	..
Key West.....	0.75	> 32	30	..
Key West.....	None	.....	..	3.9
Sandy Hook.....	2.5	> 32	30	..
Sandy Hook.....	2.0	> 32	24	..
Sandy Hook.....	1.5	17.9	18	..
Sandy Hook.....	1.25	15.2	15	..
Sandy Hook.....	0.75	11.3	9	..
Sandy Hook.....	None	.....	..	7.3 (b)
State College.....	2.5	> 32	50	..
State College.....	2.0	> 32	40	..
State College.....	1.5	> 32	30	..
State College.....	1.25	> 32	25	..
State College.....	0.75	23.5	15	..
State College.....	None	.....	..	26

(a) In ounces per square foot of sheet.

(b) Average of sheets showing failure—final average may be higher.

TABLE 12—Corrosion of Zinc in Sea Water

Reference	Form	Grade Zinc	Exposure Years	Test Location	Corrosion Rate (mpy)
9.....	Galvanized	*	4	Bristol Channel	2.5
9.....	Cast Bar	Prime Western	4	Bristol Channel	3.6
10.....	Sheet	99.1	1	Eastport, Maine	1.1
10.....	Sheet	99.1	3	Eastport, Maine	1.0
5.....	Cast	Prime Western	1	Panama	1.0
5.....	Cast	Special High Grade	1	Panama	1.0
5.....	Cast	High Grade	1	Panama	1.4
5.....	Galvanized	*	0.5	Kure Beach	1.1
5.....	Galvanized	*	1	Kure Beach	2.1
11.....	Galvanized	*	1	Southampton	1.1

\* Not stated—probably Prime Western zinc.

## Total Immersion in Sea Water

Relatively few data are available for zinc corrosion in sea water. (See Table 12.)

The International Nickel Company has investigated the effects of water velocity and iron content on rolled zinc at Kure Beach and Harbor Island Test Station.<sup>6</sup> Iron content was found to have

no detectable effect on the corrosion rate of rolled zinc (Table 13). However, velocity had a definite accelerating influence.

Other data obtained in flowing sea water (velocity not stated) at Kure Beach<sup>6</sup> are assembled in Table 14. Corrosion rate of zinc in sea water, like that in the Kure Beach atmosphere, decreases with time.

probable contributing factor was the influence of the purlin mass in slowing the drying rate of moisture condensed on the under surface. This factor can be avoided or minimized in roof construction by local paint protection. Even without these precautions, galvanized sheet life was five times that of black iron sheets of the same gauge.

From Table 10, time-to-perforation at Sandy Hook and State College will be some larger multiple of that for uncoated sheets. (Since galvanizing increased the steel cost by only 15 to 20 percent, improvement in life due to the zinc coating is obtained at very low cost per year.)

Although ASTM tests have been underway for 35 years, only in Sandy Hook's industrialized marine atmosphere (of the exposures considered here) has failure progressed far enough to rust the entire sheet surface. Available data on failures are plotted in Figure 3.

The indicated linear relation between weight of zinc coating and time to rusting has been established over many years of exposure testing by many investigators. Approximate linearity of the underside perforation curve at Key West demonstrates that even this type of failure can be delayed by the use of heavier coatings. Obviously, however, precautions to avoid underside corrosion will be a wise investment.

Calculations of coating life from zinc corrosion rates cannot be made precisely because of normal variations in coating thickness. Such calculations do have value; they approximate the correct service values. Data and calculations for the 22-gauge sheets are given in Table 11.

The contrast between the time to perforation of bare steel and the calculated coating life at Key West is striking. With the exception of the unusual perforation from the underside at Key West, no galvanized sheets were perforated after 32 years of test.

TABLE 13—Sea Water Corrosion of Iron-Containing Zinc

Fe-%	Corrosion Rate (mpy)*		
	Total Immersion	Tidal Zone	2 Feet Per Second Flow
0.0003.....	1.4	0.8	3.0
0.0008.....	0.8	0.8	2.0
0.0014.....	0.8	0.9	2.0
0.0021.....	0.8	0.9	2.0
0.006.....	0.8	0.8	2.0
0.011.....	1.4	0.9	2.0

\* Average of two 1" x 4" x 1/8" specimens exposed one year.

### Sprayed Zinc Coatings

Half tide and total immersion tests of sealed and unsealed zinc coatings on 4 by 12-inch steel panels at Harbor Island are given in Table 15.<sup>4</sup> Tests were made in sextuplicate and continued for 3.2 years.

As in the case of other types of zinc coatings, the extent of protection to the base metal depends upon coating thickness. Heavier coatings are required in the tidal zone than when totally immersed.

Additional tests were made on steel H-beam piles at Harbor Island.<sup>5</sup> The pilings were exposed for 6.3 years. Included among other tests were bare steel, hot-dip galvanized steel and zinc spray coated steel (15 mils, upper half and 10 mils, lower half—unsealed). Inspection data are in Table 16.

Since blistering and cracking are not common modes of corrosion failure of galvanized steel, events reported in this table largely represent damage during the driving of the piles.

### Zinc-rich Paint

Studies are in progress at Harbor Island<sup>6</sup> to determine the relative abilities of zinc-rich paint and galvanized coatings to protect bare steel areas under total immersion conditions. Quadruplicate 12-inch square panels are under exposure separately coated with hot-dipped zinc (1.5 oz per sq ft of surface), a silicate vehicle zinc-rich paint and an organic vehicle zinc-rich paint. Efforts were made to apply the same weight of metallic zinc in each case. Two panels of each were scribed vertically to bare widths of 1/16, 1/8 and 3/16-inch; the remaining two panels were unscribed.

These tests have now been under way for one year. No rusting has occurred on the unscribed panels nor on the silicate zinc-rich paint or the galvanized scribed panels. Scribed panels coated with a zinc-rich paint of the organic vehicle binder type showed a few rust spots in the widest scribe after four weeks. These spots have grown over the intervening exposure period until after one year the entire length of all scribes shows rust. This is not regarded as necessarily representing the true performance in sea water of the organic vehicle

TABLE 14—Corrosion of Zinc in Flowing Sea Water

Specimens (Size in Inches)	Exposure (yrs)	Corrosion Rate (mpy)
6 x 12 x 0.032 Special High Grade Zinc.....	0.5	1.9
6 x 12 x 0.032 Special High Grade Zinc.....	4.5	0.8
6 x 12 x 0.032 Brass Special Zinc.....	4	1.9
6 x 12 x 0.032 Brass Special Zinc.....	4	0.7
12 x 12 x 1/4 Galvanized 3.7 Oz. Coating.....	0.5	1.9
12 x 12 x 1/4 Galvanized 3.8 Oz. Coating.....	1	0.9
12 x 12 x 1/4 Galvanized 4.3 Oz. Coating.....	3.5	0.6
12 x 12 x 1/4 Galvanized 4.4 Oz. Coating.....	5.0	0.5

TABLE 15—Immersion Tests on Sprayed Zinc Coatings

Coating Thickness—Inch	Sealant	% Surface Damaged			
		Half Tide		Total Immersion	
		Sprayed Metal	Base Metal	Sprayed Metal	Base Metal
0.003.....	(a), (b)	80	35	60	10
0.006.....	None	60	1	50	0
0.006.....	(a), (b)	78	1	60	0
0.009.....	None	65	1	55	0
0.009.....	(a), (b)	60	1	50	0
0.012.....	None	65	0	60	0
0.012.....	(a)	70	0	70	0
0.012.....	(b)	45	0	30	0
0.015.....	None	75	0	58	0
0.018.....	None	75	0	50	0

(a) One coat chlorinated rubber.  
(b) Two coats chlorinated rubber.

TABLE 16—H-Pile Tests at Harbor Island

Coating	Top 10 Inches	2 Feet Above High Tide	Tidal Zone
None.....	Severely rusted	Severely rusted	Adherent rust
Galvanized...	Few rust spots. Blistered-cracked	Blistered-cracked, 60% rust especially flanges	Few rust spots
Zinc Sprayed.	Top and 3" from edge—severe rusting in these areas	Same as top 10"	Very little rust, no blisters

type zinc-rich paint. Further tests will be required.

Of interest in connection with these and other total immersion studies with zinc and zinc coatings is the observation that fewer types of fouling organisms attach to such surfaces than to steel. In the present tests filamentous bryozoans, tunicates and barnacles were found on the zinc and zinc-rich paint surfaces.

### Summary

Corrosion resistance of zinc in marine environments and the corrosion rate in air can be expected to be about 0.1 mpy over long exposure periods in the United States. Exposure very close to the water and the presence of sulfur gases in the atmosphere will increase this rate. Corrosion rate of iron generally will be about 25 times that of zinc in marine atmospheres. Galvanized coating life is long in this environment.

Total immersion in sea water results in a corrosion rate of 1 to 2 mpy. Increases in water velocity increase the corrosion rate.

Zinc in the form of metallic zinc dust pigment in zinc-rich paint afforded the

same amount of protection to bare steel areas that is obtained from hot-dip zinc coatings during one year in a continuing test. This was true for silicate binder type zinc-rich paint and may be true for the organic vehicle type.

### Acknowledgment

The cooperation of T. P. May and The International Nickel Company in making available unpublished data on zinc is gratefully acknowledged.

### References

1. H. R. Amber and A. S. J. Bain. *Appl Chem*, 5, 437 (1955) Sept.
2. J. C. Hudson and J. F. Stanners. *Appl Chem*, 3, 86-96 (1953) Feb.
3. E. A. Anderson. Symposium on Atmospheric Exposure Tests on Non-Ferrous Metals. ASTM, Feb., 1946.
4. E. A. Anderson. Symposium on Atmospheric Corrosion of Non-Ferrous Metals. ASTM, June, 1955.
5. International Nickel Co., Inc., unpublished data.
6. New Jersey Zinc Co., unpublished data.
7. Report of Subcommittee XIV. Committee A-5. *Proc ASTM*, 54, 110-122 (1954).
8. International Nickel Co and American Zinc Institute, unpublished data.
9. J. N. Friend. *J Inst Met*, 39 111 (1928).
10. J. C. Hudson. *Corrosion of Iron and Steel*. Chapman and Hall, Ltd., London, pages 154 (1940).
11. 15th Report of Committee of the Institution of Civil Engineers, London (1935).

Any discussion of this article not published above will appear in the December, 1959 issue

# Corrosion Problems Associated With Sour Gas Condensate Production\*

By D. R. FINCHER

## Introduction

**D**ISCOVERY OF sour gas condensate production in the Smackover Lime formation of the New Hope Field was made in 1953. This field is located in Franklin County, Texas.

Drill stem testing of the discovery well indicated this formation to contain 10 to 18 mole percent of hydrogen sulfide in addition to 6 to 8 mol percent carbon dioxide. Corrosion and the brittle type failure of metals associated with hydrogen sulfide were anticipated for all future sour operations in the area.

A pilot plant was constructed in 1957. This plant was designed to separate the liquid hydrocarbons from the gas by low temperature separation and to dry the residue gas for injection into the reservoir. It was not designed to remove the acid gases except for the gas utilized for fuel. It was expected that experience would be gained in handling sour gases to pressures of 6,000 psi and at the same time that reservoir information would be obtained to indicate the most economical method of production to deplete the reservoir.

## Producing and Injection Wells

The top of Smackover Lime formation is encountered at 11,800 ft to 12,300 ft, and the formation bottom hole temperature is from 270 F to 275 F. Bottom hole pressure is 6,000 psi. Thickness of the producing formation is between 0 and 600 ft, and has an average permeability of 0.2 millidarcy.

It is necessary to acidize each well in order to establish optimum production rates. Some of the acid jobs have been as large as 31,000 gallons. After a well is completed and ready for production, it will usually produce 2 to 5 million cubic feet of gas per day with a condensate yield of 140 to 150 barrels per million cubic feet of gas. This wet gas has a specific gravity of approximately 1.25 (Air = 1.0) while the residue gas for injection has a specific gravity of 0.95. Flowing tubing pressures range from 1,800 psi to 3,000 psi, depending upon flow rates.

From the time that the reservoir was discovered to the present date, inhibition has been deemed a necessity. The discovery well was completed as shown in Figure 1 to provide a convenient method of inhibition. This completion utilizes a chemical injection valve set above the packer, and the annulus is filled with

## Abstract

Sour gas condensate production was established from the Smackover Lime formation in Franklin County, Texas during 1953. Reservoir studies indicated a need for cycling of the sour gases for greater ultimate recovery of liquid hydrocarbons. A pilot plant was built to remove liquids and to compress these gases containing 10 to 18 mol percent hydrogen sulfide and 6 to 8 mol percent carbon dioxide to 6000 psi for injection into the reservoir. Control of corrosion was considered in the completion of the wells as well as in the design of the plant. Failures of equipment were minimized by the use of inhibitor and selection of materials. Experience to date has indicated that corrosion can be controlled and these toxic gases safely produced and processed.

8.4.3

inhibitor-diesel oil in a mixture of one part inhibitor to forty parts diesel oil. Pumping of similar oil-inhibitor mixture into the annulus at the surface displaces inhibitor into the bottom of the tubing string. Springs in the chemical injection valves are preset so that a pressure differential of 1,500 psi is required to open the valve to admit inhibitor into the tubing.

Completion of the discovery well utilized a chemical injection valve that was

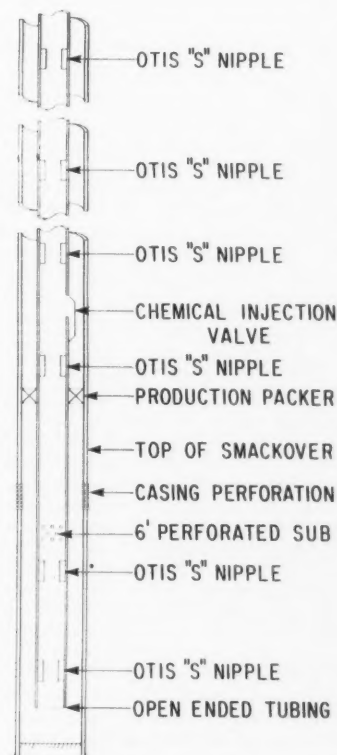


Figure 1—Typical Tidewater well completion.



About  
the  
Author

D. R. FINCHER is corrosion engineer for Southern Division of Tidewater Oil Co., Houston. He received a BS in chemical engineering from Texas A and M College in 1948. He was employed by Tidewater after graduation and has been active in corrosion work since 1949. He is chairman of NACE Unit Committee T-1B on Condensate Well Corrosion.

not wire line retrievable. Wells completed since that time have utilized wire line retrievable valves; very little trouble has been experienced with these valves.

In all wire line operations the practice of lubrication of the wire line with inhibitor has proven to be very beneficial. Without the protection by inhibitor, it is probable that a wire line

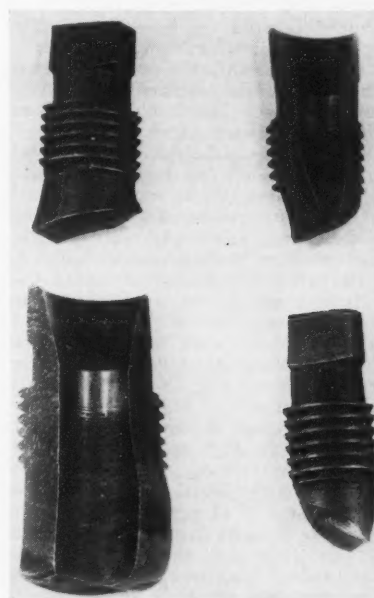


Figure 2—Typical failure of wellhead chokes and valves.

\*Submitted for publication March 2, 1959. A paper presented at the Fifteenth Annual Conference, National Association of Corrosion Engineers, Chicago, Illinois, March 16-20, 1959.



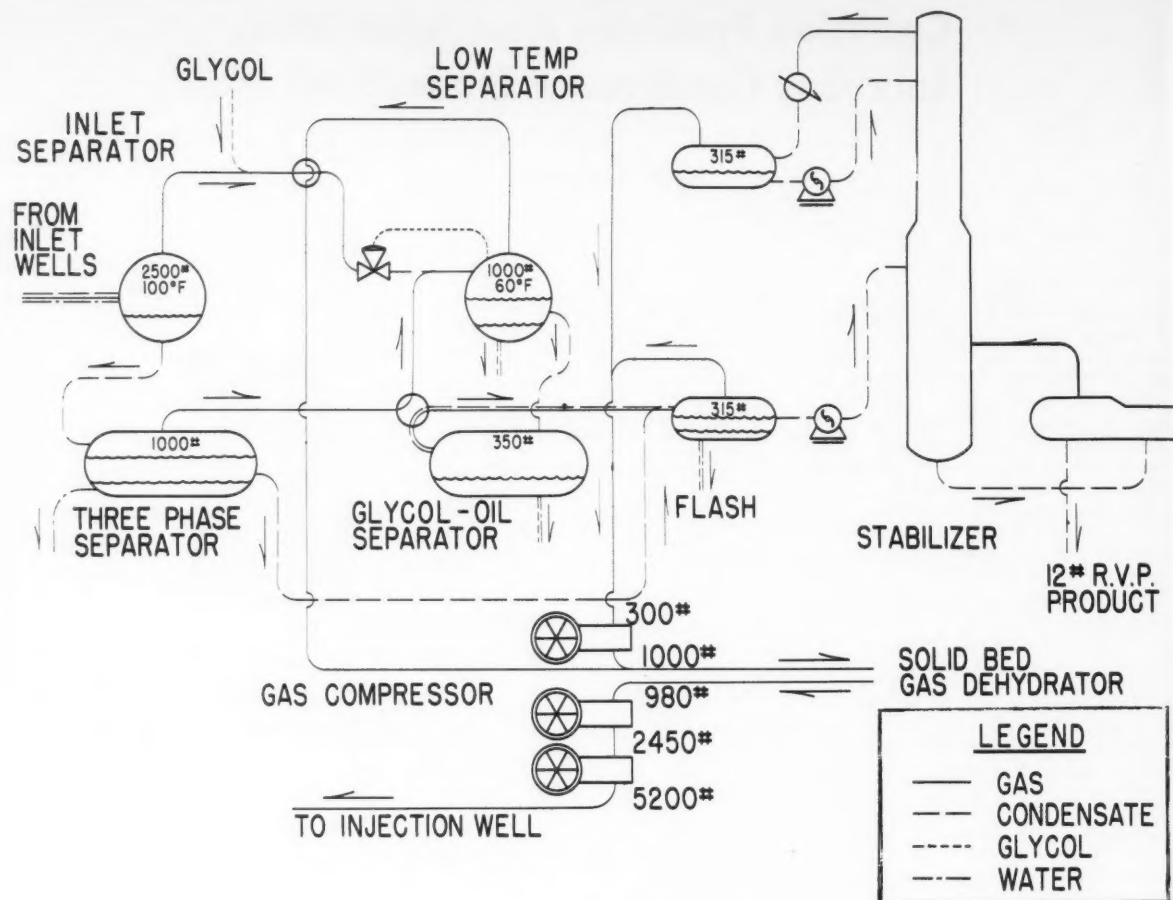


Figure 3—Flow diagram, low temperature separation at New Hope, Smackover Field.

run in and out of a well will experience a rapid failure. Failures are of a brittle nature and the line can usually be snapped between the fingers. A similar program of inhibitor lubrication of swab lines has proven equally satisfactory. Another worthwhile practice has been the storage of wire line inhibitor solutions when the lines are not in use.

Maintenance of bottom hole chemical injection valves has been a relatively minor problem. Much of the success of these valves is attributed to the cleaning of the annular surfaces of mill scale and mud used in drilling and completion. Each well had the mud circulated out with fresh and salt water until clean returns were obtained. Salt water was used to increase hydrostatic head, and it appeared to remove additional mud. An acid wash consisting of 2,000 to 3,000 gallons of mud acid followed with more circulation with fresh and salt water completed the first step in cleaning of the annular surfaces.

Following the initial washing, 1,000 to 2,000 gallons of 15 percent hydrochloric acid were pumped down the annulus and into the formation. Inhibited diesel oil was used to displace the acid into the formation, and the well was circulated with inhibited oil before setting the tubing into the packer. Swabbing was elim-

inated by leaving the inhibited oil in the tubing, and this step also allowed the coating of the tubing with inhibitor prior to producing the well.

Selection of an inhibitor for the casing annulus has presented problems. Experience with the discovery well indicated some inhibitors cause a precipitation in the lower section of the annulus, with resulting difficulty in pumping. Various lab tests of diesel oils and inhibitors at high pressures and temperatures allowed selection of more soluble inhibitors and the elimination of the problem.

J-55 grade tubing was used for all producing wells. In all wells, the top 3,000 ft of the string was 2½ inches EUE instead of a full string of 2 inches EUE. This was done to increase safety factors. All injection wells were completed with 2½-inch N-80 grade tubing, although the minimum yield strength was controlled between 70,000 and 90,000 psi. The J-55 and controlled yield strength N-80 were used to minimize brittle type failures associated with hydrogen sulfide. Injection wells were not completed with chemical injection valves, although the annuli were loaded with inhibited diesel oil. Prior to producing an injection well for testing, an inhibitor squeeze was performed to provide protection for the interim period when no inhibitor could

be injected. Inhibitor squeeze, in addition to providing corrosion protection, also increased well productivity. This is believed to be through the detergency of the inhibitor aiding the formation to be cleaned of mud.

All of the wells were shut-in several months prior to continuous production. During these periods, at least two barrels of inhibitor-oil mixture were pumped into the well, one barrel from the annulus at the chemical injection valve and the other directly into the tubing at the surface. As a result, inhibitor-oil mixture was squeezed into the formation. One well, completed in October 1954, produced at the rate of 1,682,000 cubic feet per day with a wellhead pressure of 1,883 psi (dead weight gauge). Upon completion of testing, the well was shut-in and the tubing loaded with inhibited oil. Inhibition was commenced on a monthly basis, and 81 barrels of inhibited oil were injected into the formation before the well was again produced. When tested again in early 1957, the well produced 2,168,000 cubic feet per day with a wellhead pressure of 2,234 psi (dead weight gauge). This indicated that the productivity of the well increased after the formation received the inhibitor-oil mixture.

Use of plastic coated tubing was con-

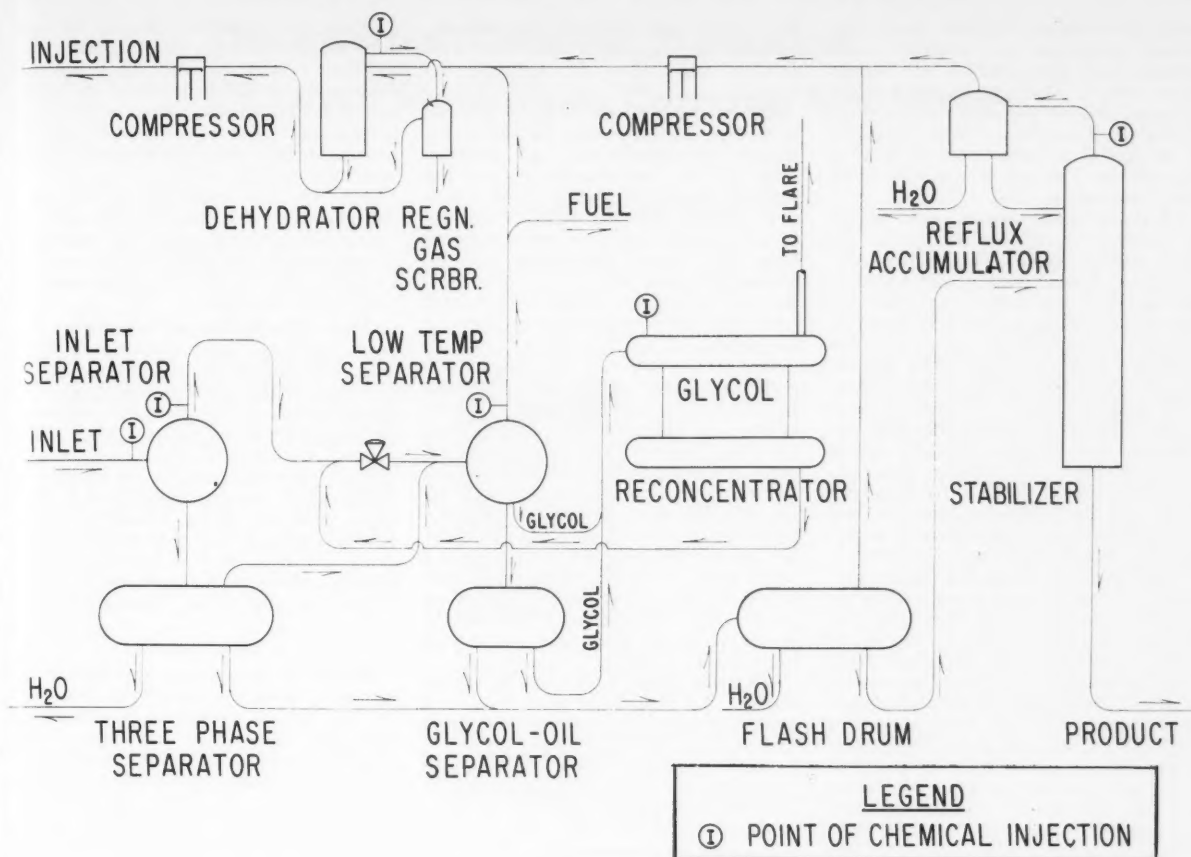


Figure 4—Flow diagram, corrosion inhibitor injection points, New Hope pilot plant.

sidered early in the life of the reservoir. A bottom hole pressure bomb was coated with a baked phenolic coating and placed in the bottom of a well for 72 hours. When recovered, this coating had failed by blistering. Subsequent testing of coatings at the surface indicated that the performance of all coatings tested in this service left much to be desired. Many coatings became impregnated with gases and failed due to blistering even after being removed from the environment.

To date there have been no failures of tubing or casing. Corrosion of tubing is being controlled by using 0.5 quart of an organic corrosion inhibitor per million cubic feet of gas. Criteria of control have been observed by periodic use of tubing caliper surveys and visual inspection of wellhead equipment.

Some failures of wellhead chokes and valves have occurred as shown in Figure 2. These failures have been eliminated by changing the point of injection of inhibitor and/or by changing the material used in manufacturing in order to provide some inherent corrosion protection. Brittle type failures at wellheads are found in highly stressed or very hard materials. Valve stems made of K-Monel have been used successfully although they are oversized for additional strength. Springs made of Inconel have become necessary in practically all valves and

controls. Valves and wellhead equipment have generally been standard materials with the exception of stems, springs, gauges, trim, etc. There have been no serious failures of any wellhead equipment.

### Design of Plant and Gathering System

Prior to construction of the plant and gathering system, considerable study and effort were put into the design of the system. As a result, general recommendations included the following:

1. Use standard materials of construction and depend upon inhibition for protection.
2. Dehydrate the sour gas before compression up to 6,000 psi for injection.
3. Air-cool high pressure gas streams within the plant.
4. Use corrosion meter probes to determine corrosion rates and degree of control being obtained.
5. Eliminate "dead ends" and provide adequate means of drainage at points where water collects.
6. Internally coat all storage tanks with a coal tar-epoxy coating.
7. Use corrosion resistant materials only as necessary for control valves, trim, stems, seats, gauges.
8. Use a direct fired closed heating

system with a circulating non-corrosive media, not exposed to hydrogen sulfide.

9. When possible, use welded connections or flanges instead of threaded connections. Stress relieve all plant welds.

Figure 3 shows a simplified flow diagram of the process. Full stream well-head effluent flows into the plant inlet separator and free liquids are removed. Gas from the inlet separator enters a low temperature unit where glycol is added to prevent freezing and to partially dehydrate the gas. Gas from the low temperature unit proceeds to the first stage discharge scrubber and to the dry bed dehydrator. Dehydrated gas passes to the second stage suction scrubber, then is compressed and scrubbed before entering the third stage of compression. The gas is discharged into the injection wells after flowing through the third stage discharged scrubber.

Liquids from the low temperature unit (glycol, water, and condensate) flow to the glycol-oil separator for removal of the glycol solution. Condensate from the inlet separator passes to a 3-phase separator, then to a flash tank, which also receives condensate from the glycol-oil separator. The condensate proceeds to a stabilizer where a 12-lb Reid Vapor pressure natural gasoline is fractionated.

Low pressure gases from the flash

tanks, the stabilizer, and the glycol condensate separator are scrubbed, compressed, and discharged to the second stage system. These gases are not dehydrated before the first compression. Excess water is removed from the glycol in the glycol reconcentrator by heating the solution. Fuel gas is sweetened in an amine sweetening unit.

Corrosion meter probes were placed in strategic locations throughout the plant and in the flow lines at the wells. Within 72 hours, these probes began to fail and leak gas badly. The plant was shut down and all probes were removed. Another manufacturer of probes was contacted and a suitable probe was designed. These probes were used successfully without failure, but have not been in the wide service that originally was planned. One problem with the use of probes is that the corrosion losses recorded vary with flow rates through the plant and lines, making corrosion rate data questionable. This problem is particularly bad in two phase systems.

After removal of all the failing corrosion probes, coupons were used to record corrosion rate data. Generally, corrosion rates were 1 mpy or less at all points that received some inhibited liquid hydrocarbon from the field. Coupons exposed in gases separated from the liquid showed corrosion rates from 5.0 to 10.0 mpy. As an example, the gas off of the inlet separator corroded a coupon at 5.61 mpy while the inlet stream (containing the full well stream effluent) corroded the specimen at a rate of 1.06 mpy. Similar data were obtained in the gas from the low temperature separator and the top of the stabilizer. This indicated the need for additional inhibitor injection points.

Coupons removed from the glycol system also showed corrosion rates of 5 to 10 mpy. The cooling water system corroded coupons at the rate of 5.0 to 44.0 mpy with no great consistency in rate data being obtained. Inhibitor injection points within the plant were selected as shown in Figure 4.

Because the gathering system was constructed to handle large volumes of gas, a low linear velocity was experienced initially. Corrosion was anticipated at points where water would collect, such as road crossings. The oil soluble inhibitor used in the wells was not expected to fully protect the lines at these points. Hence, it was decided to use a neutralizing type volatile amine at each wellhead to raise the pH of the water collecting in the flow lines. This morpholine type inhibitor was beneficial in raising the pH of the water removed at the plant to a value of 6.0 to 6.5. Some difficulty from the use of this inhibitor has been experienced in lines producing salt water in

that calcium carbonate scale precipitated, reducing the capacity of the line. This problem was solved by reducing the dosage.

Other injection points for the neutralizing type inhibitor were in the glycol system, the regeneration gas scrubber from the dry bed dehydrator, and the stabilizer overhead. All of these points were selected for this inhibitor because of the low pH values of water removed from these vessels. Laboratory data indicated that the efficiency of most commercial corrosion inhibitors increased when the pH of water was at least 5.5 or greater.

Due to the presence of hydrogen sulfide, the cooling water system could not be treated with a phosphate-chromate inhibitor. An inhibitor made of polyphosphate and ferro-cyanide was selected and used in conjunction with controlled pH. Difficulty was experienced in controlling the pH. The plant flare was located approximately 150 feet away from the cooling tower and was 50 feet high, but winds of a certain direction would cause SO<sub>2</sub> fumes to be absorbed in the cooling tower water. Lowering of the pH by two units in two hours was not uncommon.

After the initial eight months of operation, the plant was shut down and all of the equipment visually inspected. Observations were as follows:

1. Corrosion was severe in the process system at any point where glycol solutions were in contact with steel. Corrosion was negligible in other areas.
2. Cooling water corrosion and/or scale was experienced throughout the plant.
3. Dehydration of the gas effectively alleviated corrosion in the high pressure systems.

Laboratory study of glycol solutions saturated with hydrogen sulfide indicated that a combination of pH control and a film forming inhibitor would provide better than 90 percent protection from corrosion. The original neutralizing inhibitor was the morpholine type. Laboratory testing revealed that a single inhibitor combining diethylamine and a conventional water-dispersible, film-forming corrosion inhibitor would effect the desired protection. Consequently, the morpholine type inhibitor was discontinued in the glycol system and in the flow lines, and the use of the combination inhibitor was begun. The morpholine type was continued at other points in order to avoid possible damage to dry-bed desiccants and/or emulsion problems from the combination inhibitor.

Cooling water treatment was changed from phosphate-cyanide treatment to zinc-organic-phosphate treatment. These changes made possible better control of pH within the cooling tower.

While the plant was shut-in for the first inspection after eight months, the stabilizer was filled with diesel oil inhibitor mixture and circulated at 300 l for 24 hours. This was done to simulate a "squeeze" type of treatment and to provide bubble caps, downcomers, etc., with an inhibitor coating.

After the first inspection and the subsequent changes in the corrosion mitigation program, coupon corrosion rates decreased greatly. By mid 1958, all coupon corrosion rates within the process system were below 1.0 mpy.

After 15 months of operation, the plant was again shut down for inspection. This inspection indicated no further corrosion of the glycol system. A greatly reduced rate of corrosion was observed in the cooling water system. Caliper surveys of an injection well tubing string revealed that no corrosion was occurring. Other points exposed to dehydrated sour gases were not visibly corroded. Tanks internally coated with coal tar-epoxy suffered corrosion only at holidays in the coating. Much more rigid specifications for coating application were indicated.

### Conclusions

Safety is one of the most important phases of an operation such as described in this paper. Adequate protection of equipment is of great importance. The experience and data gained in producing and processing sour gas condensate from the New Hope Field Smackover Lime formation indicate both obligations of safety and protection of personnel and equipment can be fulfilled by:

1. Design of equipment to remove water at all possible points.
2. Use of standard equipment with special corrosion resistant materials at critical locations.
3. Use of a constantly supervised corrosion inhibitor program.
4. Design of equipment with adequate strength, yet using ductile materials.

Constant study and re-evaluation of data, means, and methods are also most important features in any such program.

### Acknowledgment

The writer expresses his appreciation to the management of Tidewater Oil Company for the opportunity to present this paper and also to M. J. Epperson, J. R. Mason, and J. R. Mottley of Tidewater Oil Company for their valuable assistance in the preparation of this paper.

### Reference

1. R. H. Poetker and J. D. Stone, Corrosion Control of Gas Lift Wells, *Oil and Gas J.*, 54, No. 62, 100 (1956) July 9.

Any discussion of this article not published above will appear in the December, 1959 issue



# The Internal Cathodic Protection Of Large Steel Pipes Carrying Sea Water\*

By JOHN H. MORGAN

## Introduction

ONE OF the most rapidly growing fields in which pipelines are used to carry electrolytes is the transport of cooling water for industrial plant and power stations. Resistivity of water will vary with its source. The water, being required in large quantities, will be pumped at high velocity. This factor plus the increased temperature resulting from the cooling process will increase the rate of the corrosion of any metal pipes used to discharge the water. Steel is the material most commonly used in such pipe. Because sea and estuary water are the waters most commonly used in Great Britain, only the protection of steel pipes carrying these liquids will be discussed here. And since the problem of cooling water is one of transporting large quantities of water, only the corrosion of large pipes will be considered.

## Anti-Corrosive Techniques

In general there are four anti-corrosive techniques that can be employed in such a system: (1) the pipe metal can be lined to reduce the electrolytic corrosion, (2) the internal surfaces of the pipe may be protected cathodically (if economically feasible), (3) inhibition can be employed in the case of a recirculating water system, (4) the pipe material can be selected to withstand the corrosive attack either by using a suitable metal or by using a non-metal such as concrete or a plastic.

The first two methods (i.e., coating and cathodic protection), can be used as complementary treatments. It might be useful here to consider the application of various combinations of these two measures.

Perhaps the best method of approach will be to consider the cathodic protection of the pipe walls in the presence of various coatings. This way the coating can be defined by its electrical resistance; as techniques which improve coatings or which vary the cost of the cathodic protection are developed the economics of the various schemes can be compared. One system will be ignored in this type of treatment: the use of an almost perfect coating which can be employed without cathodic protection. To be acceptable a perfect coating must be cheaper than a combination of an imperfect coating with cathodic protection.

## Cathodic Protection of Bare Pipe

The simplest method of achieving protection in a pipeline is to use a con-



About  
the  
Author

JOHN H. MORGAN is responsible for the cathodic protection department in the Sturtevant Engineering Company Limited, London, England. He holds an MA degree in physics from Cambridge University; he first worked on guided missiles, then entered cathodic protection as a research scientist. His principal contributions have been on the spread of protection, lead alloy anodes, and the protection of aluminum. He has written a book on cathodic protection due to appear in Fall 1959, and is a member of NACE, IEE, and SCI.

centric cylindrical anode as shown in Figure 1A. The current density is uniform over the bare pipe surface and the electrolyte resistance per unit length is readily calculated. The resistance of each foot length will be:—

$$R = \frac{\rho}{2\pi \times 30.5} \log_{10} \frac{D}{d} = 0.012 \rho \log_{10} \frac{D}{d} \quad (1)$$

where  $\rho$  = ohm cm  
D = Diameter of pipe, inches  
d = diameter of anode, inches

Thus a 3-inch diameter rod anode in a 30-inch diameter pipeline which contains water at 100 ohm-cms will have a electrolyte resistance of 1.15 ohms per foot. If a current density of 4 milliamperes per square foot of pipe surface is required for protection, that is 31 milliamperes per foot run, the driving voltage required would be 36 mV.

The current required for protection

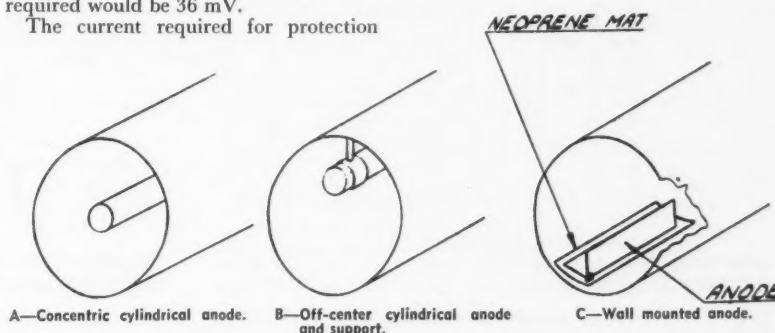


Figure 1—Anodes for cathodic protection inside a pipeline.

## Abstract

The internal cathodic protection of large steel pipe carrying sea water is discussed both from the practical and the theoretical viewpoint. Systems considered involved use of such devices as concentric cylindrical anodes, off-center cylindrical anodes, wall mounted anodes, and central point lead alloy anodes fed with impressed current from a dc source. The cathodic protection was applied to both bare and coated pipe. Testing was done both in the laboratory and on a full scale level.

The designing of a potential measuring device and the determination of protection criteria are considered briefly. Other topics discussed include coating the pipe interior, computing the costs of cathodic protection, and determining the relationship between anode separation and anode diameter in pipes with the same coating and electrolyte.

It was found that coatings will effect the largest economies on the smaller diameter pipe where the cost of the cable is lowest and where smaller anode supports can be used with small anodes. At the moment the most economical method of protection seems to involve the use of a cheap readily applied coating of reasonable resistance and cathodic protection from point anodes mounted at or close to the center line of the pipe.

5.2.3

will increase directly as the pipe size increases, that is twice as much current will be required in a 60 inch diameter pipe as in a 30 inch diameter pipe. Also the resistance of each foot length will increase as the logarithm of the ratio of the pipe to anode diameters; that is the resistance of each foot length will double if the anode is made 0.3 inch diameter instead of 3 inches diameter in a 30 inch diameter pipe. The extremely low resistances and driving voltages required with this method allow its exploitation in waters of high resistivity.

The continuous concentric anode has some disadvantages, mainly due to its bulk. In large diameter pipes it may be simpler to mount the anodes closer to the walls either by holding them a short distance away—Figure 1B—or by employing techniques similar to those used to attach anodes to the outside hulls of ships—Figure 1C. Where the anode is

\* Submitted for publication September 25, 1958.

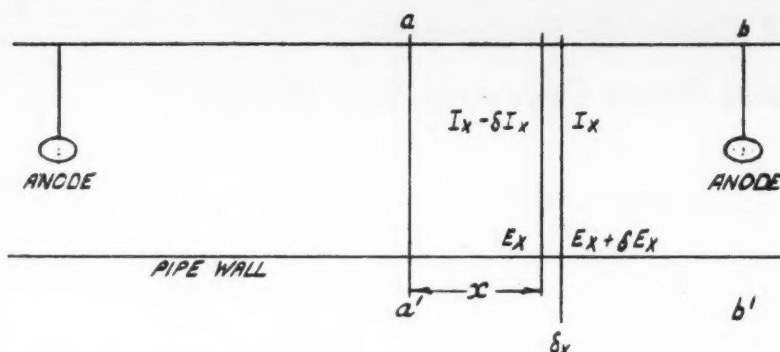


Figure 2—Central point anode system in a pipe.

arranged to be off-center, the resistance between anode and pipe wall will be slightly reduced. Some portions of the pipe will receive over-protection so that the current required to ensure protection everywhere will be greater than previously. This in turn will mean that a higher driving voltage will be required.

The low driving voltage required with the concentric anode system, particularly in low resistivity electrolytes, suggests that protection might be achieved without the anode being continuous. The anode might, for example, be made of 5-foot lengths of metal each separated by a distance of five feet. A similar result will be obtained if the anode length is reduced without extending the anode separation providing sufficient anode material remains to give an economical driving voltage and sufficient life.

The recent development of lead alloy anodes<sup>2</sup> suggests that both these properties can be obtained in saline water using a small, almost point, impressed current anode. Inasmuch as power is cheaply available at many sites it was decided to investigate a cathodic protection system for the interior of pipelines using these anodes. It was felt that this type of investigation would be profitable because the arrangement was susceptible to a simple mathematical treatment<sup>3</sup> and because it could be used to study not only the spread of protection but also the current densities required and degree of polarization obtained under a variety of conditions. Many of these results could then be applied to the extension of the

engineering techniques used and to other methods of cathodic protection.

The impressed current system was used because it could be analyzed to show how sacrificial anodes could be employed to achieve similar protection.

#### Central Point Anode System in a Coated Pipe

If the water in the pipe is considered to be acting as a leaky electrical transmission line then current will flow along it and leak away to the steel pipe wall through the coating. If a small length of the pipe is considered then the current flowing longitudinally through the water will cause a small change in the water potential. Similarly the electrical potential across the coating will cause the current flowing in the water to be reduced by the amount that flows to the metal.

Two central point anodes are shown diagrammatically installed in a pipe in Figure 2. The symmetry of the system suggests that only the section between  $aa'$  and  $bb'$  need be considered and this is assumed to contain water of resistivity  $\rho$  ohms cms and to have a coating with a conductance of  $g$  mhos per sq cm. The pipe has a diameter of  $D$  cms so that if the small section length  $\delta x$  is considered, the cylinder of water will

have a resistance  $\frac{4\rho}{\pi D^2} \delta x$  ohms and

the coating will have a conductance  $g\pi D\delta x$  mhos. At point  $x$  there will be a potential change  $E_x$  by virtue of the

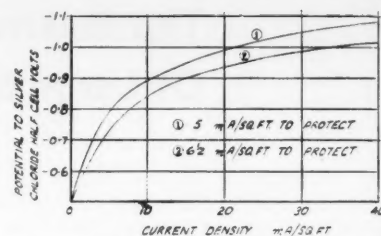


Figure 3—Typical polarization curves for sea water in motion.

cathodic protection and this will cause a current  $\delta I_x$  to flow through the coating.

$$\delta I_x = E_x g \pi D \delta x \quad (2)$$

Similarly the current  $I_x$  flowing in the water will cause a change potential  $\delta E_x$  in the small cylinder considered,

$$\delta E_x = I_x \frac{4\rho}{\pi D^2} \delta x \quad (3)$$

and these lead to the differential equation

$$\frac{\delta^2 E_x}{\delta x^2} = \frac{4\rho g}{D} E_x \quad (4)$$

which has as a solution

$$E_x = A \cosh ax + B \sinh ax$$

where

$$a = \sqrt{\frac{4\rho g}{D}}$$

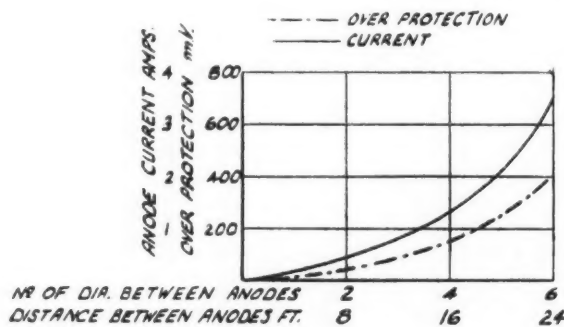
The boundary conditions are that at  $x = 0$ ,  $E_x = E_m$  the minimum potential change necessary for protection and that  $\frac{\delta E_x}{\delta x} = 0$

$$\therefore E_x = E_m \cosh ax \quad (5)$$

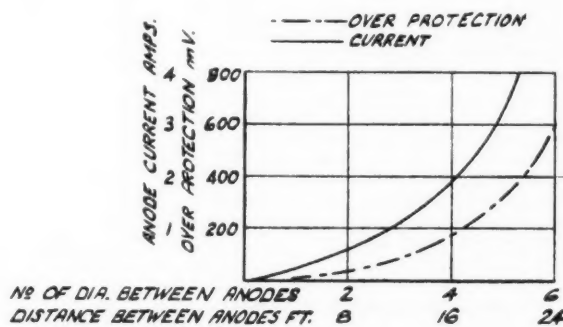
If a particular amount of over-protection can be tolerated opposite the anode then in a series of pipes containing the same resistivity water and similarly coated the maximum permissible separation between the anodes varies as the square root of the pipe diameter, that is  $\frac{E_x}{E_m} = \cosh ax$

$$\therefore ax = \cosh^{-1} \frac{E_x}{E_m} = \text{constant}$$

$$\therefore x \text{ varies as } \frac{1}{a} \text{ or as } \sqrt{D}$$



A—When 5 ma/sq ft required for protection.



B—When 6 1/2 ma/sq ft required for protection.

Figure 4—Over-protection and anode currents at various anode spacings for 48-inch diameter pipe.

that is  $x = kD^{1/2}$  (6)

Near to the anode, however, the pipe will not act as a transmission line so that the maximum distance between the anodes will be the sum of two distances, one as detailed above and the other the influence of the anode. The spread of protection will be

$$S = C(D) + kD^{1/2} \quad (7)$$

where  $S$  is the inter-anode distance,  $D$  the pipe diameter,  $k$  is a constant and  $C(D)$  some function of  $D$ . The influence of the anode will be small (i.e.,  $C(D)$  will be less than  $kD^{1/2}$ ), so that  $C(D)$  need not be determined accurately. Also it will be a constant number of diameters and  $C(D)$  may be estimated as one diameter. Now equation 7 becomes

$$S = D + kD^{1/2} \quad (8)$$

The value of  $k$  will depend upon the water resistivity and the coating conductance. It will vary inversely as the square root of the resistivity and inversely as the square root of the conductance per unit area of the coating. Thus, if the maximum permissible distance is 20 feet in a 60-inch diameter pipe when the coating has a resistance

of 50 ohms per square foot, then if this resistance is increased 100 times, the distance between anodes can be calculated.

$$S_1 = D + k_1 D^{1/2}$$

$$S_2 = D + 10 k_1 D^{1/2} \text{ since } k_2 = 10 k_1$$

$$S_2 = 155 \text{ feet.}$$

This means that the anodes can be spaced 155 feet apart. Had there been a direct dependence of this distance upon the coating resistance, the anodes could have been placed 2,000 feet apart. Similar variations will occur with changes in electrolyte resistivity, though it is a condition in deriving equation 8 that  $C(D)$  is small compared with  $kD^{1/2}$  and this condition must hold.

In the above calculations it has been assumed that the parameters of the coating and the water resistivity are known. While the latter is easily determined, the former may best be found by a practical determination in one size of pipe and then the distance calculated for pipes of other diameters. To test the formula a series of experiments have been carried out on bare steel pipes of various diameters ranging from laboratory determinations on small pipes to tests on large diameter pipes on an actual site.

#### Practical Tests on Bare Steel Pipe

It will not be possible to ascribe a particular conductance to the bare steel surface as there will not be a linear relationship between the potential change and the current density. For moving sea water two typical polarization curves are shown in Figure 3 when 5 milliamperes/sq ft and  $6\frac{1}{2}$  milliamperes/sq ft are required to achieve protection. It is possible to use this information to calculate arithmetically the over-protection and anode current at various anode spacings. The results of this are shown in Figure 4A when 5 milliamperes/sq ft is required for protection and Figure 4B when  $6\frac{1}{2}$  milliamperes/sq ft is required to achieve protection for a 48 inch diameter pipe. Curves of similar shape would be obtained for other pipe diameters, the

maximum anode separation again varying as the square root of the diameter.

In laboratory tests two short lengths of steel pipe were used and these had internal diameters of approximately 1 inch and  $1\frac{1}{2}$  inches. The pipe was coated on its outer surface and held vertically in sea water as shown in Figure 5. Cathodic protection was applied to the inside of the tube at the lower end of the tube and water was circulated to cause a slow flow of water in the tube. The pipe potential along the tube was investigated using a salt bridge extension of capillary tube. These investigations suggested a maximum anode separation in the tubes and the results are shown in Figure 6A and 6B.

Figure 6A shows the variation of potential along the length of the 0.91 inch internal diameter pipe after 3 days and 8 days protection in slowly moving sea water. The general form of the curves is that predicted from the mathematics. A separation of 22 diameters could be achieved between two central point anodes.

Figure 6B is a plot of the polarization that occurred in a 1.56 inch internal diameter tube at two levels of current. The potentials remained at the level reached after 20 hours under continued protection. Other tests showed that in the 1.56 inch tube a spread of 18 diameters could be expected from central point anodes.

Field tests on larger pipes were made using three anodes and a series of half cells to measure the pipe potential as shown in Figures 7A and 7B. A fixed current was fed into the center anode and then the current into the outer pair was varied to cause protection to be just achieved at the point of minimum pipe potential change. These minima were arranged to be approximately the same distance either side of the central anode. The "inter-minima" distance was measured and this showed the maximum permissible distance between anodes at that particular current.

Three sizes of pipes were available on

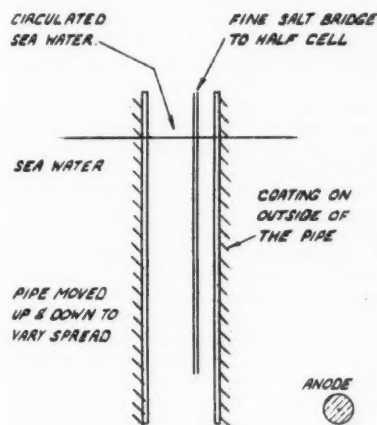
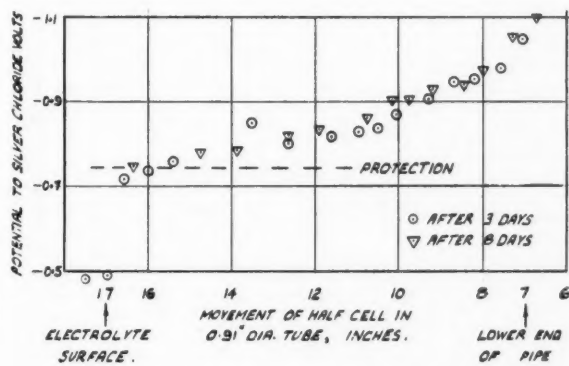
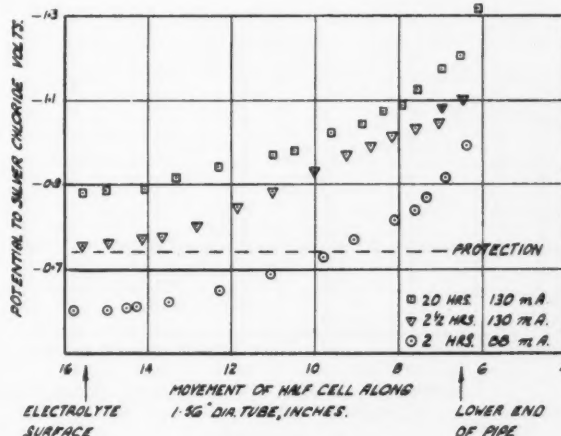


Figure 5—Laboratory test arrangement.



A—0.91-inch internal diameter pipe after 3 days and 8 days protection in slowly moving sea water.



B—1.56-inch internal diameter tube at two levels of current.

Figure 6—Variation of potential along pipe.



site, 16 inch diameter, 24 inch diameter, and 36 inch diameter. Short lengths of these were strung end to end through reducers, and three anodes were placed in each section. In the 16 inch pipe these were 8 feet apart, in the 24 inch pipe 10 feet apart, and in the 36 inch pipe the anodes were 12 feet apart. A string of saturated silver chloride half cells was assembled so that the half cells were 1 foot apart and the string was fixed in the pipe close to the pipe wall. The half cells were not positioned exactly in relation to the anodes but were used as a distance reference frame. As the significant measurement is the distance between minima this can be determined without exact reference to the anode positions.

The velocity of the water in the pipes was measured and was arranged to be varied from a slow replacement at no measurable velocity up to speeds of 5 feet per second. This unfortunately was attainable only in the smallest diameter pipe and the smaller speeds were used on the other pipes. As the effect of the velocity was small, particularly upon the ultimate spread of protection, this limitation of flow velocity did not invalidate the experiments. Three typical results are shown in Figures 8A, 8B, and 8C.

#### Criterion of Protection

It was assumed that the pipe metal was adequately protected when its potential relative to a saturated silver chloride half cell was  $-0.75$  volt. This cri-

terion was adequate in the tests and at these potentials a thin grey film formed on the steel surface. The results show some variation caused by polarization and velocity but these are small and are generally included in the small circles indicating the results in Figure 9. These results are compared with two others reported and with a curve of the type  $S = D + k D^{1/2}$  with which it is in good agreement.

#### Pre-Engineering Tests Planned

So far the tests described have shown that there is a simple relationship between the anode separation and the pipe diameter in pipes with the same coating and electrolyte. To complete the experiment in a series of tests involving various pipe coatings and electrolytes should be made. These tests are comparatively difficult to perform both because the effects of coating application and coating deterioration under such conditions are not fully known and because no great number of practical installations are available upon which to make tests.

When tests are carried out two methods can be used. A coating conductance can be measured, say by using a concentric anode in a small length of pipe, and this related to the pipe diameter and water resistivity to determine the maximum spread that can be obtained; this technique would test the formulae given earlier. Or alternatively, a current drainage survey can be made on part of the point anode installation and from this the spread to be expected in other similar pipes can be determined by the method already described for bare pipe lines. In both cases the results should be the same and as in each case similar

measurements must be made, there seems little to choose between them. For purpose of estimating the anode separation it would be useful to be able to compute the separation with various coatings and from this point of view the former method may be the more rewarding. Certainly it would be interesting to test the theory developed even if only to prove consistency of the predictions. An opportunity exists here for additional work.

For the present discussion, assume that the spread factor  $k$  varies inversely as the square root of the coating conductance. Then in the 60-inch diameter pipe described earlier, it is possible to plot the expected spread of protection against the coating resistance per square foot. This has been done in Figure 10.

#### Full Scale Installation on Bare Steel Pipe

Having proceeded so far with the experimental work a full scale installation for the cathodic protection of the internal surfaces of the sea water cooling system was made using central point lead alloy anodes fed with impressed current from a dc source. The anodes were designed so that they could be withdrawn from the pipes and all electrical connections carried through the pipewall. The anode was attached to an insulated steel support as shown in Figure 11. This support was covered in PVC\* and the anode was then attached so as to seal the edge of the coating. A layer of adhesive was used to bond the lead to the PVC both having been machined so as to form the pair of matching surfaces. The insulated support was brought through a gland to the outside of the pipe where electrical connection was made to it. The gland was attached to a pipe flange and the assembly was inserted into the pipe via a T junction, which was formed by welding a small neck flange to the pipe. The earlier anode resembled a croquet mallet the two striking faces of which were lead alloy. In order to reduce the size of the T branch, and consequently the work involved in fitting the equipment, the an-

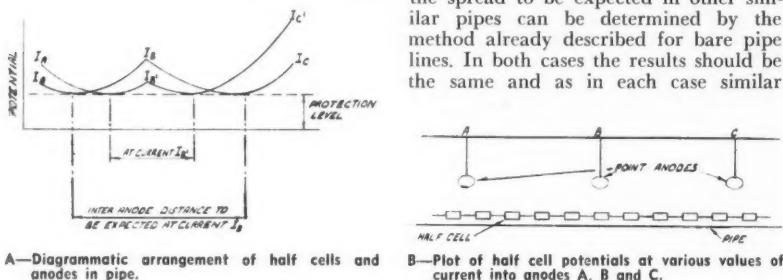


Figure 7—Testing arrangement and results.

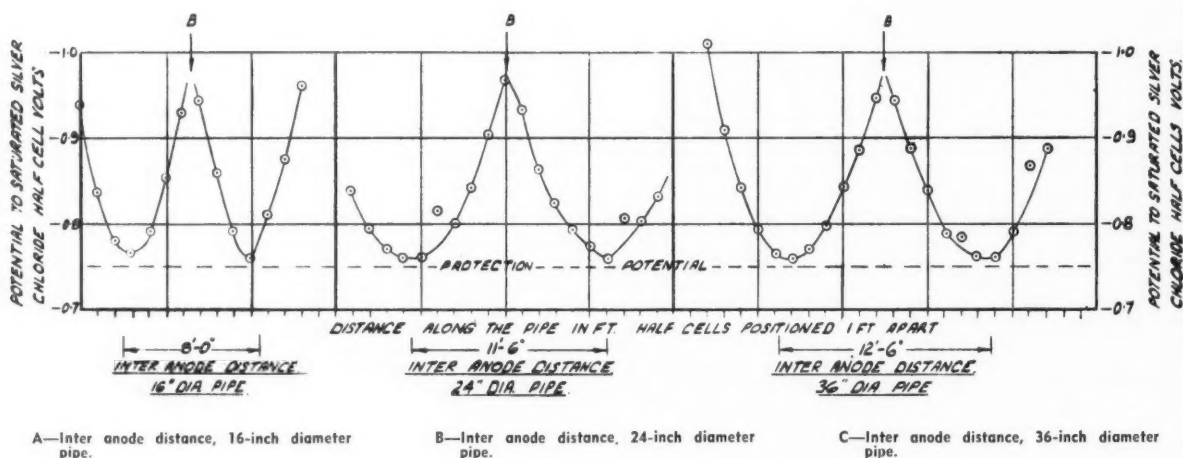


Figure 8—Potential to saturated silver chloride half cell.

seems  
pur-  
ation  
npute  
s and  
ormer  
Cer-  
at the  
prove  
a op-  
work.  
that  
ly as  
duct-  
pipe  
plot  
against  
foot.

e ex-  
ation  
inter-  
g sys-  
lead  
current  
e de-  
rawn  
con-  
wall.  
lated  
This  
d the  
seal  
f ad-  
o the  
so as  
faces.  
ought  
f was  
ed to  
is in-  
ation,  
small  
r an-  
e two  
alloy.  
ne T  
k in-  
e an-

POTENTIAL TO SATURATED SILVER  
CHLORIDE HALF CELLS VOLTS

ter

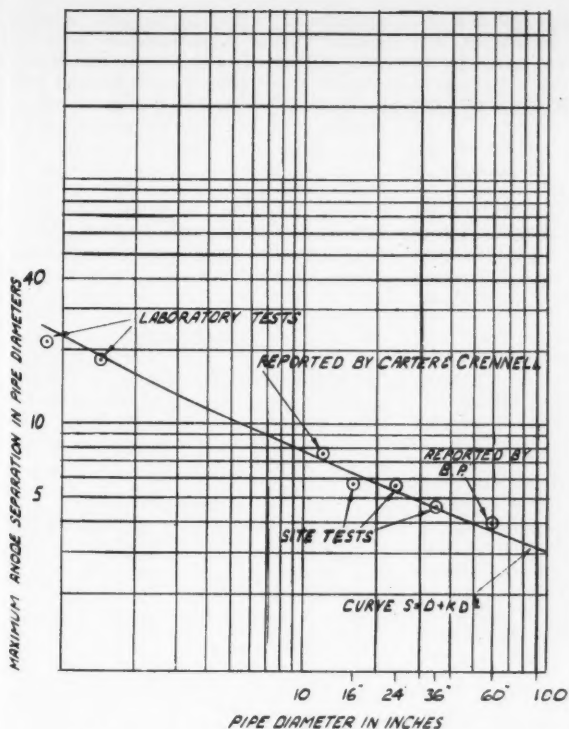


Figure 9—Spread of protection determined from several sources.

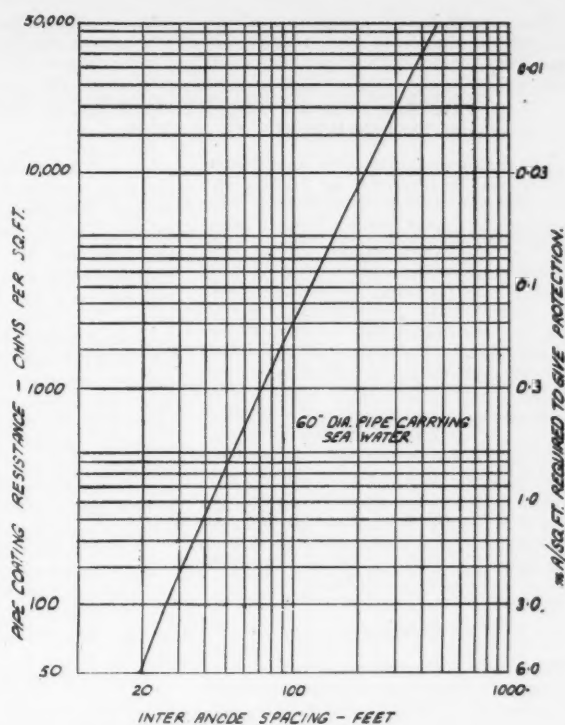


Figure 10—Plot of expected spread of protection against coating resistance per square foot.

ode and holder were changed in shape to resemble a hanging lantern, the lead occupying the position of the glass bowl, as in Figure 11. Anodes have been in service since late 1957 and are proving to be entirely satisfactory.

The pipes protected were bare steel and carrying sea water so that the anodes were separated along the pipeline by less than the distances indicated in Figure 9. Where an anode was close to a bend or near a bifurcation, smaller spacings were used. At a bend the outside dimension of the bend was measured. This measurement was used as the spread distance, while at junctions the anode was either considered to give almost normal spread up each arm if located at the point of bifurcation or, if placed elsewhere, its spread was considered to be reduced in a similar manner to the reduction at the bends. It was assumed that valves would consume additional current and the anode separation was reduced by one diameter at each valve as a consequence.

#### Potential Measuring Device

To prove the adequacy of the cathodic protection some potential measuring device had to be used. As it seemed difficult to use permanently placed half cells, a new potential measuring unit was developed. This consisted of a porous ceramic plug held in an insulating plastic holder and inserted through the pipe wall, as in Figure 12. The porous plug became saturated with the electrolyte

\* Later models in neoprene.

and by placing the half cell plug in contact with the outer side of the ceramic plug then the potential of the metal inside the pipe could be determined. The unit is protected by a steel box and water-tight cap so that even at high pressures no serious leak occurs should the porous plug fail. No failures have been reported from the extensive practical use of this device.

An alternative arrangement is suggested which uses a pure zinc plug in place of the porous ceramic plug and the zinc potential relative to the pipe is then measured. This potential depends to some small extent upon the electrolyte. While this potential is sufficiently constant to be useful in an actual protection installation it did not appear to be sufficiently accurate for experimental work.

The dc network which fed the anodes was supplied from a number of transformer rectifier units. From each of these a cathode lead was taken to the pipes and a series of anode busbar leads to the various anodes in the unit's vicinity. Each anode was coupled to one such busbar through a variable resistor and these were adjusted to give protective potentials to the pipe metal. This system was used because of the variety of pipe sizes and the complexity of the installation. With other engineering jobs where long uniform lines are being protected all the anode currents could be adjusted from the transformer-rectifier. Because the installation was adjacent to a refinery the units were made to similar specifications to flame proof equipment and mineral insulated cable was used throughout.

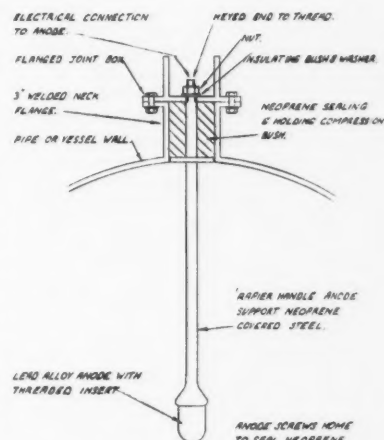


Figure 11—Anode and holder.

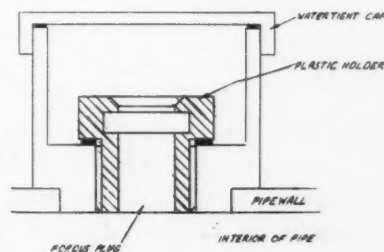


Figure 12—Porous plug potential measuring device.

The installation is complete and the components that have been running for some time, confirm the experimental results.

#### Coating the Pipe Interior

The maximum permissible anode separation can be increased by coating the pipe interior with a resistive film. This coating must have certain special properties to be entirely suitable for use with cathodic protection. Most important of these is the fact that the coating must not soften under the influence of the cathodic reaction either by degradation of the vehicle or the pigment. The flow of water in the pipe will reduce this tendency and little damage will occur to most coating systems that will withstand the effects of alkali softening at potentials of  $-0.9$  volt to silver chloride on steel in static sea water. Another detrimental effect in sea water is the absorption of water by the coating, particularly by electro-osmosis under the influence of the cathodic potential. This absorption lowers the coating resistance.

#### Economics

The cost of the cathodic protection of a bare steel pipe can be computed per foot run of pipe. This cost will include the cost of the anodes, cable and power unit. Now, if the pipe is coated the an-

odes will be less in number and each one will give a smaller current output. The latter will not cause a large reduction in cost as the one used in the protection of the bare pipe was of little weight and small in size.

The reduction in the number of anodes will be inverse of the increase in anode separation so that the cost of the anodes calculated per foot will be reduced. The cost of providing the power unit etc. will be small compared with the anode costs so that though this will be reduced it will not be of great significance. The cost of the dc network will be approximately the same as it will have to extend along the pipe and the cost per foot of this will also be the same. The cost of such cable may be high compared with the cost of the anode unit, for example, the anode cost may be \$1.40 per foot run and the cable cost when installed may be nearly half this. These figures might apply to a 60 inch line in which a spread of 60 feet was achieved. To increase the spread to 120 feet by using a better coating would only reduce the cost per foot of the installation from say \$2.10 to \$1.40 per foot while the cost of the superior coating may be more than an extra 4.5¢ per square foot.\*\*

From this analysis it can be seen that

\*\* The costs in dollars and cents are computed from English money at  $\$2.80 = \pounds 1$  for a hypothetical case and are intended only to be indicative of the method of assessing the economies.

coatings will effect the largest economies on the smaller diameter pipes where the cost of the cable is lowest and where smaller anode supports can be used with small anodes. Also the system described, though ideal for bare or poorly coated pipe, must be compared with the off-center or side-mounted anodes for use in well coated pipes. Before these methods can be compared in detail some tests similar to those described above will be necessary. No doubt as this problem grows the various methods will be used and a closer study can be made of the problem of protection using a combination of a coating and cathodic protection. At the moment the most economical method seems to involve use of a cheap readily applied coating of reasonable resistance and cathodic protection from point anodes mounted at or close to the center line of the pipe.

#### References

1. The Magnesium Anode. A publication of Dow Chemical Co. Michigan U.S.A. 8, No. 2 (1958) July.
2. J. H. Morgan. Lead Alloy Anodes Tested at 20 amps/sq. ft. *Corrosion*, 13, No. 7, pages 128 and 130 (1957) July.  
J. H. Morgan. Lead Alloy Anode for Cathodic Protection. *Corrosion Technology*, 5, No. 11, 347-352 (1958) November.
3. J. H. Morgan. Spread of Protection. *Corrosion Technology*, 3, No. 6, 194-196 (1956) June.
4. L. T. Carter and J. T. Crennel. The Cathodic Protection of Ships Against Sea Water Corrosion. *Trans. Inst. Naval Arch*, 97, page 413 (1955).  
J. H. Morgan. Cathodic Protection. Leonard Hill (Books) Ltd. (1959).

Any discussion of this article not published above  
will appear in the December, 1959 issue

### TECHNICAL PAPERS ON CORROSION WELCOMED

Authors of technical papers on corrosion are invited to submit them for review without invitation to the Editor of Corrosion. Write for "Guide for the Preparation and Presentation of Papers" sent free on request to prospective authors.



## Duct Anode Development and Experience in

# Protection of Underground Cables From Corrosion\*

By J. E. JOHNSON

### Introduction

THE USE of impressed distributed anodes pulled into a duct and employed in conjunction with a direct current power source for cathodic protection of lead sheathed cables in underground conduit is a relatively new idea. The first technical papers on the subject were presented in 1955<sup>1</sup> and a U. S. patent was issued on August 20, 1957.<sup>2</sup>

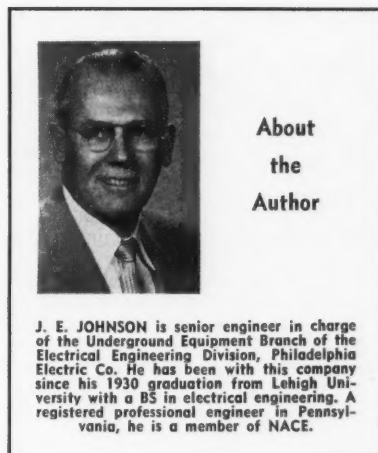
Before the development of the articulated duct anode, continuous anodes such as scrap cable, special anode cable and galvanic ribbons were pulled into duct systems and used for corrosion control. These systems were effective, but the life of the anode was too short. Development of a long life duct anode was undertaken because of its low installation cost and close electrical coupling with the protected cable which minimizes interference with other utilities.

### Experience with Graphite Anode Elements

In January, 1954, the first articulated duct anode<sup>1</sup> on the Philadelphia Electric Company System was installed. This anode was made of graphite rod elements 2 inches in diameter by 18 inches long, with rounded edges and equipped with a No. 8 AWG rubber insulated copper wire lead or pigtail approximately 2 feet long. The copper wire lead was sealed into the connection hole at the end of the graphite element with a compound and rubber gasket. Individual elements were attached on five-foot centers along a No. 4 AWG rubber insulated, neoprene jacketed header wire with a wrapping of 20-mil thick polyvinyl tape at both ends. The copper wire was served and soldered to the No. 4 header wire, and the splice was insulated with rubber and polyvinyl tape.

Life of this anode design was estimated to be 20 years. In addition, it was felt that failure of a single element with this type construction would not leave any section of cable exposed because the adjacent elements would supply sufficient protection current to cover the gap.

Further improvement upon the design was made on an anode installed by New Jersey Bell Telephone Company<sup>3</sup> by passing the header wire through the graphite and by making internal connections instead of binding elements to the header wire and making external connections. Element length was reduced to 12 inches



About  
the  
Author

J. E. JOHNSON is senior engineer in charge of the Underground Equipment Branch of the Electrical Engineering Division, Philadelphia Electric Co. He has been with this company since his 1930 graduation from Lehigh University with a BS in electrical engineering. A registered professional engineer in Pennsylvania, he is a member of NACE.

to permit pulling around the shorter radius bends in the smaller sized telephone ducts.

The effect of a continuous wire was achieved by cutting the element in half radially and threading the center of each half to fit the threads on a special connector. The wires were inserted through the holes in the center of the halves of the elements; wire ends were spliced by compressing them in the connector. Then the element halves were screwed together on the threads of the connector. Cement and compound were used to make seals. Chances of losing the connection were minimized by using the center type connection rather than the end type, but, if an element were damaged or expended, the wire would be severed and protection lost beyond this point.

Excellent results at various locations in stopping corrosion of lead cable sheath have been obtained with cathodic protection using articulated duct anodes. However, time showed this system was not trouble-free.

After two years of operation, a routine test was made in Chester, Pa., on an anode system of the original design shown in Figure 1. In one section the anode had been set to operate at 10 volts between the anode and cable sheath with an average output of 10 milliamperes per element. In the other section the anode had been set to operate at 4 volts between the anode and cable sheath with an average output of 15 milliamperes per element. Portions of these two man-hole-to-man-hole sections were inopera-

### Abstract

Discusses tests conducted on high silicon iron anodes in ducts containing silt. Graphite anodes in silt filled ducts have short life because gases, liberated by electrolysis and trapped by silt, attack the graphite binder, tape adhesive and wire insulations.

Presents illustrations of new anode elements and discusses new materials used. Tests conducted for best spacing of elements are given.

7.7

tive, and the two sections were removed for visual inspection. The following conditions were noted:

### Section One

Heavy silt deposits had collected over almost the entire section of 55 elements. The terrain was level.

Electrical grade polyvinyl tape used to secure elements to the header wire and as a protective cover over the splices had lost its adhesion.

Two splices had failed from corrosion, and others had minor corrosion of the copper.

Visual inspection of the elements showed severe deterioration as follows:

(a) Severe graphite loss had occurred on the element end which had the electrical connection.

(b) Severe size reduction occurred at scattered locations along each element with the most severe material loss occurring near the connection end and adjacent to and partially under the tapes used to secure the element to the header wire. Softening of the graphite also occurred at these points. Softened material had the consistency of putty.

(c) Because of the erosion and softening of the element material, sealing gaskets were separated from the graphite. In some cases, there were voids in the sealing compound. This exposed the copper connection which was then destroyed by electrolytic corrosion.

### Section Two

Very little silt had collected around the 92 elements because ducts were on a grade.

Polyvinyl tapes had lost adhesion.

One element was separated at the location where it was taped to the header wire. At this point the header wire insulation had been destroyed, and the wire was corroded away for several inches.

Individual elements showed severe loss of graphite at the connection and other local areas along the elements, but softness was not as acute as in Section One.

General condition of the removed anodes appeared to follow the same pat-

\* Submitted for publication January 8, 1959. A paper presented at a meeting of the 15th Annual Conference, National Association of Corrosion Engineers, Chicago, March 16-20, 1959.

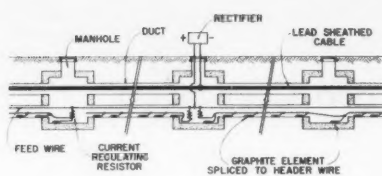


Figure 1—Anode in electric conduit line.

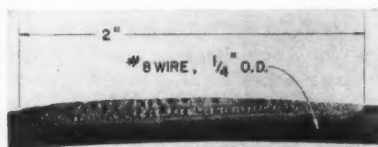


Figure 2—Deterioration of polyvinyl insulation on header wire after four years of operation.

tern as described in a report by NACE T-2B Technical Committee.<sup>4</sup>

After this severe deterioration was found, anodes were inspected from two manhole-to-manhole sections of the original installation adjacent to the Delaware River. This installation had operated about four years with 4 to 7 volts between the anodes and cable sheaths and an average output of 20 milliamperes per element. This is a tide-water area where large amounts of silt accumulate in the ducts. Condition of these anodes was similar to those inspected in Chester except that deterioration had not been as rapid and the greatest graphite loss was at element ends.

Examination of the anodes removed and later laboratory tests indicated that silt in the ducts was indirectly responsible for causing the graphite elements to deteriorate. Silt that surrounded the elements trapped the acid products and gases generated in the electrolysis process. These injurious substances concentrated around the elements and attacked the tape adhesives and the graphite binder.

When the Chester anodes were removed, deterioration of the rubber and neoprene wire insulation was observed under the tape used to attach the element to the header wire. When the anodes along the Delaware River were removed, insulation of header, feeder wires and element leads also was badly deteriorated. Water filled blisters had formed between the rubber insulation and the neoprene jacket of the header wire. At scattered locations, the polyvinyl feeder wire insulation was swollen and spongy.

Figure 2 shows the blister shaped swellings about two inches long that formed on the header wire where it lay against the elements near their ends. Insulation resistance of four deteriorated sections was measured after submersion in tap water for 72 hours. Resistance of three was infinite and the fourth was 12 megohms, but the insulation's spongy condition indicated that a rapid attenuation of insulation resistance would have occurred if the wire had been left in service.

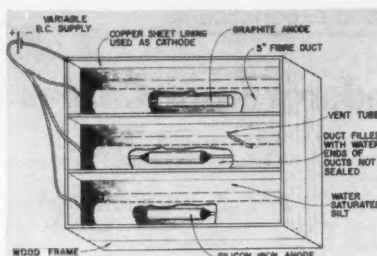


Figure 3—Anode test box.

### Design and Test of Silicon Iron Anode Elements

Failure of the graphite elements and the wire insulation reduced the expected life of the protection system to less than one-tenth of that anticipated. This trouble indicated that a more durable element material should be used and that a wire insulation was needed to resist deterioration from electrolysis by-products. At the time the Chester anode failures were discovered, another area was under investigation that would involve the protection of the cable in approximately 18,000 feet of duct bank. Since this duct bank contained important subtransmission lines, development of an improved anode was undertaken.

A silicon iron anode 1½ inches in diameter by 60 inches long equipped with a feed wire having polyethylene insulation and a polyvinyl jacket was laid in deep silt on the Delaware River bottom. After operating for two months at 63 volts and 2.5 amperes, it was removed for inspection. Metal loss from the anode was negligible, but water blisters had formed between the polyethylene insulation and the polyvinyl jacket of the wire. Also the insulation of a lifting wire wrapped around the center of the anode was severely deteriorated and had the same general appearance as the polyvinyl insulation on the Delaware Avenue feeder wire shown in Figure 2.

A laboratory test of silicon iron elements duplicated field installation with outside influences removed such as stray current, unpredictable pH, water flushing etc. Anodes and test box used are shown in Figure 3. One element was placed in a 5-inch fibre duct packed with silt; another was placed in a water filled 5-inch duct equipped with a vent tube. A graphite element was placed in a 5-inch duct packed with silt.

The three ducts were placed in a box filled with silt and kept saturated with tap water throughout the test. Copper lined sides and bottom of the box were dimensioned to simulate the anode surrounded by cable. The anodes were energized and the current densities adjusted to approximately 40 milliamperes per square foot.

After two months of operation, the graphite element showed definite loss of material and softening at the ends. Most pronounced loss primarily was at the electrical connection end. Silicon iron elements showed no physical changes or loss of metal.

Though the test box was kept satu-

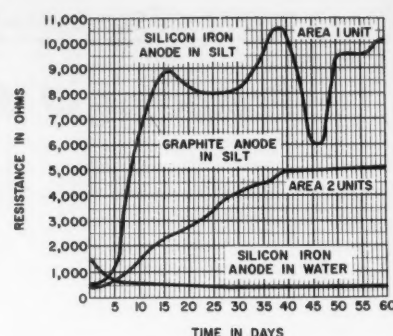


Figure 4—Anode resistance.

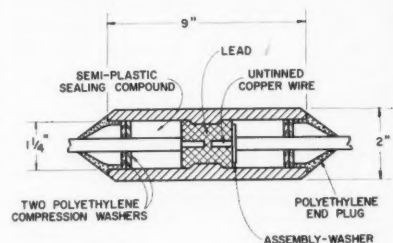


Figure 5—Silicon iron anode used in laboratory tests.

rated, direct current drove most of the water from the silt adjacent to the silicon iron and graphite elements in the silt packed ducts. At the end of the test this silt was hard and dry. This action places a definite limit on the current output of an element. With 125 volts on the silicon iron element a current of 12 ma was obtained. If this voltage were raised, the current would increase temporarily and then return to about the same value. With 790 volts impressed, a current of only 17 ma was obtained. Resistance of elements buried in silt is plotted in Figure 4.

Resistance per square foot of these elements was 20 times that of the silicon iron pilot which was in the vented water filled duct. Variation of silicon iron element resistance with time is attributed to the formation of shrinkage cracks in the hardened silt surrounding the elements.

### Design of Silicon Iron Anodes

#### Selection of Materials

Characteristics demonstrated by silicon iron on test and in service indicated that this material was ideal for a duct anode.

The element design (shown in Figure 5) was produced in cooperation with a silicon iron products supplier. Inside diameter of the element was 1¼ inches except for a 1-inch section at the center where the diameter was reduced to one inch. This design could be readily molded at the foundry.

Because rubber, neoprene and polyvinyl wire insulations had failed, ten major cable manufacturers were given a report of operating experience and were requested to submit a recommendation for a suitable cable. Seven manufacturers re-

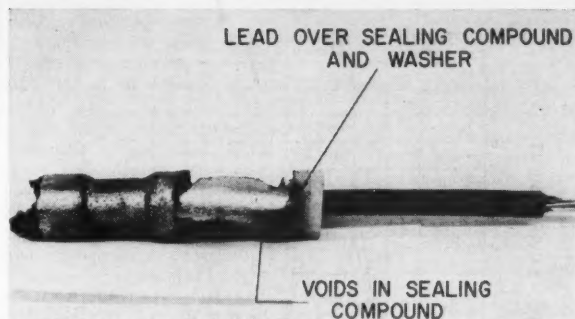


Figure 6—Internal connection and seals of silicon iron anode tested.

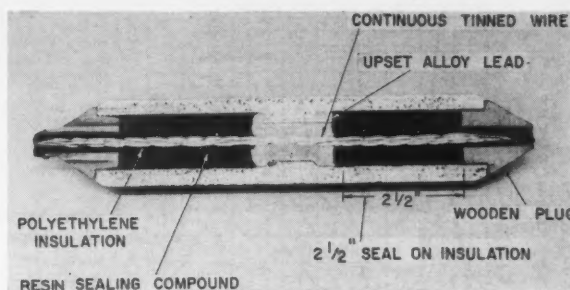


Figure 7—Improved silicon iron anode element.

plied. In all cases, black high molecular weight polyethylene insulated wire was recommended. This material has a high resistance to erosion\* from current flow along its surface and has excellent resistance to environmental cracking.

#### Assembly

In assembly of the element, approximately one inch of insulation was removed from the end of the two copper wires. The wires were centered in the element. An assembly washer was installed on one wire. The element was then placed in a vertical position with the assembly washer on the bottom and a measured amount of molten lead poured into the element so that the reduced diameter section in the center was surrounded with lead. The assembly washer acted as a dam for the lead. Semi-plastic compound was used to fill the space on either side of the lead plug. Two polyethylene washers and a tapered polyethylene cap were forced into each end of the cylinder.

Tensile strength of the solder connection was tested. The connecting wires began to pull out of the element at 796 pounds. One pulled completely out at 852 pounds, the other slipped one quarter of an inch. This tension is well below the 1100 pounds minimum breaking strength of No. 4 wire. The wire was untinned which resulted in a weak soldered connection.

Figure 6 shows the internal parts of the element tested. Voids can be seen in the semi-plastic sealing compound. Solder from the connection ran along the sealing compound to and over the inside polyethylene washer. This left only the outside polyethylene washer to seal the anode connection. A better assembly was produced later, but characteristics the designer intended were difficult to obtain. High resistance developed in the connection in a large number of silicon iron elements after installation.

For improved element design, the assembly shown in Figure 7 was made. Individual elements were assembled on a continuous polyethylene insulated wire, permitting utilization of the full tensile strength of the copper conductor. With this arrangement the connection in each

element supplies only the mechanical strength necessary to pull that element into the duct and maintain good electrical contact; the non-continuous connection had to be strong enough to pull all the elements behind it into the duct.

First attempt in assembling the new type anode used commercial lead to make the connection between header wire and element. This connection tended to have high resistance because as the lead cooled it shrank. Voids developed between the element material and the lead. When the resin sealing compound was poured, it ran between the element and the lead, filling these voids and partially insulating the element from the wire. Upsetting (compressing) the lead from one end radially expanded the plug, eliminating voids and greatly reducing contact resistance. The latest element design uses a tinned copper header wire and an alloy of lead, tin and antimony instead of commercial lead.

Tests showed that these changes lowered the electrical resistance between header wire and element below 400 microhms at  $-5^{\circ}\text{C}$ . At  $20^{\circ}\text{C}$  the value was too low to detect in the presence of the 1750 microhms resistance of the seven feet of wire between elements of the anodes tested. Strength of the connection was increased to a point where the wire will break before it will pull out of the element.

Because few materials adhere to polyethylene, various sealing compounds were tried. After several experiments, a resin was found that adhered to the polyethylene insulation with a bond of about 200 pounds per square inch. Approximately  $2\frac{1}{2}$  inches of wire were imbedded in the resin on element ends. Tests on several elements showed no leaks along the wire or along the junction of resin and silicon iron from  $30^{\circ}\text{F}$  to  $160^{\circ}\text{F}$  with 125 psi air pressure applied to the interior during 12 daily temperature cycles.

Tapered wooden plugs were used in the element ends to prevent the leading end from catching on obstructions when pulled into the duct. Twelve elements were submerged in water to make a swelling test of the wooden plugs. After 72 hours of soaking, expansion was insufficient to cause any damage to the element.

#### Shipping

Previously, anodes were shipped on reels, but anodes of latest design can be

packed readily in a wooden crate which is more economical and easier to handle and ship than a reel.

#### Economy

This anode is now being assembled at a 40 percent saving over the original design using graphite elements. A major portion of this saving is in the element material itself. Additional savings are made possible by improved production methods, cheaper handling and shipping and elimination of splices and mechanical connectors.

#### Test for Selection of Element Spacing

Because considerable saving could be realized if the element spacing were increased, a special articulated test anode was made with 19 elements connected electrically to four separate header wires so that various element spacings from 5 to 30 feet could be tested.

This anode was pulled into a typical conduit containing four lead sheath cables bonded together with No. 8 wire. Tests were made by reading the voltage between a reference test electrode in an empty duct adjacent to the anode and the cable sheaths when the test potential was periodically connected and disconnected. Plotting these data gave a voltage profile of the cable along the entire length of the anode.

Starting with a low average current density of 2 ma per element, tests were made with element spacings of 30, 15, 10 and 5 feet. The reference test electrode was moved to another empty duct with an increased distance from the anode and the same tests repeated. Tests were repeated with average current values of about 5, 10 and 15 ma per element. All test currents were applied only for sufficient time to read the instruments to avoid gas film formation on the cables.

Results of tests at 5- and 15-foot spacings are shown in Figures 8 and 9 for simplicity and ease of interpretation of the curves. Irregular conditions are typical of existing duct where it not only follows the ground contours but it must also change elevation to clear other underground structures, thereby causing wet and dry sections of duct. These variations account for peaks and valleys in the voltage curves.

It is important to note how the voltage readings vary with respect to the spacing between anode and empty duct in which

\*When an anode is buried in mud, current takes a path of least resistance along wire insulation surface, forming elongated wavy grooves. This phenomenon was called erosion by the cable manufacturers.



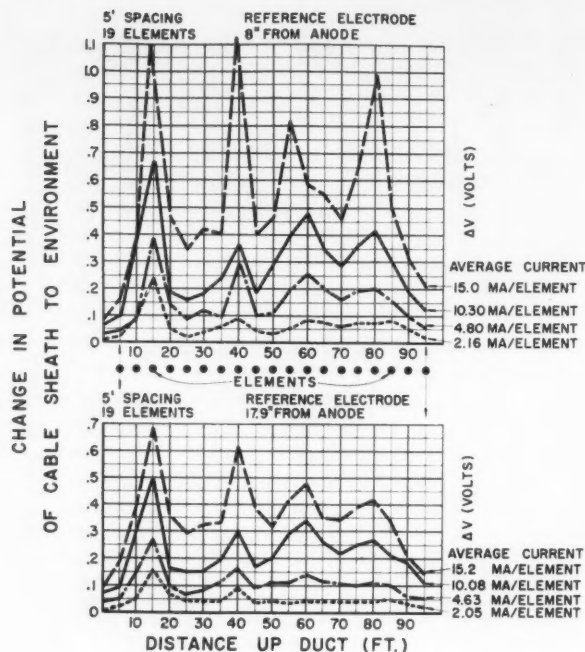


Figure 8—Coupling voltage characteristics with elements at 5-foot spacings.

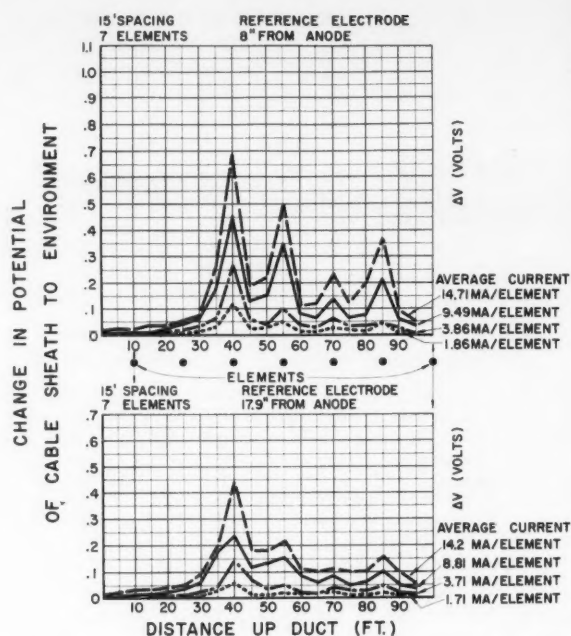


Figure 9—Coupling voltage characteristics with elements at 15-foot spacings.

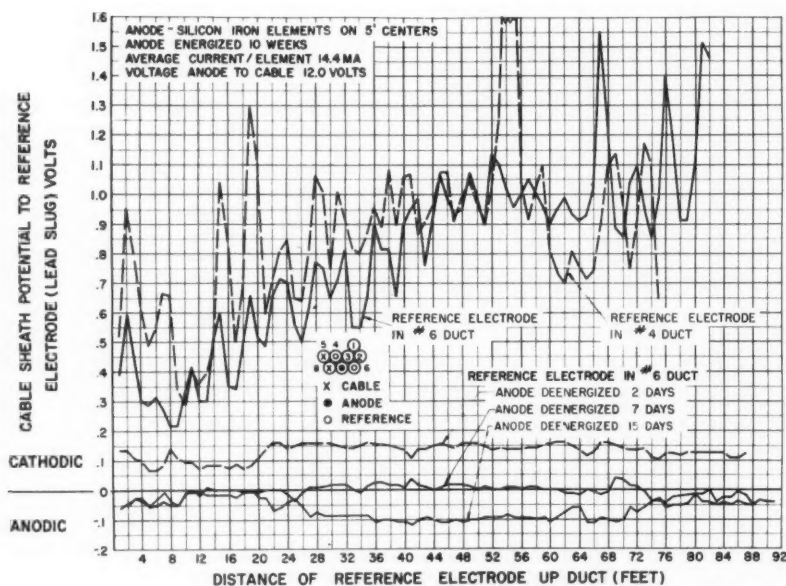


Figure 10—Cable sheath potentials to reference electrode.

the reference electrode was placed. The valleys remained almost the same, but the peaks became much sharper when the reference electrode was placed nearer the anode. Therefore, care was required when evaluating data to correlate voltages with relative position of the cables, anode and reference electrode to assure sufficient protection for all cables without over protecting any of them.

The curves of Figures 8 and 9 show

the voltage relations without gas films on the cables. As the hydrogen film forms on the cables, peak voltages at the elements will not change much, but the lower cathodic voltages between elements will increase and provide protection in these sections. This behavior was observed in the data presented in Figure 10.

Data from Figures 8 and 9 were used for anode design for 3.4 miles of duct

bank because the terrain, soil resistivity and pH at the test location was typical of the whole area. Optimum element spacing was selected at 15 feet, and 18,000 feet of anodes were installed at a cost of approximately \$30,000, not including engineering and testing, to protect cable with a replacement value of over \$400,000.

Experience revealed that original duct anode arrangement which placed an element on the manhole floor resulted in over-protection of the cables in the manholes where the cables were submerged. The present design has eliminated the manhole element, but an element placed within two feet of the duct mouth on at least one side of the manhole was needed to maintain protection continuity. Eliminating the element from the manhole avoided a possible short circuit between element and cable sheath and any shock hazard to personnel.

#### Field Installation Data

In August, 1958, the first two manhole-to-manhole anodes of the new design were installed on Delaware Avenue in an area where ducts are heavily silted, to replace graphite element anodes installed in 1954. In these two sections the elements were spaced on five-foot centers to correspond with the original anode design.

After ten weeks of operation, cable sheath potential measurements were made every foot along 100 feet of duct bank with respect to a lead slug reference electrode pushed into an empty duct. These readings are plotted in Figure 10. The two upper curves show that the anode current was distributed to such a

degree that position of individual elements was obscured. Range of sheath potential to reference electrode was large but typical of other installations in this area.

The three lower curves show that an extensive polarization film had developed around the cables which was very slow to dissipate after the anode had been de-energized. Between the fifth and seventh day there was an average potential change of approximately 0.15 volts. Between the seventh and fifteenth day there was almost no potential change in the locations between 1 and 25 feet and 75 to 90 feet, but between these two sections there was an average potential change of approximately 0.10 volts. This indicates that the duct is more completely filled with silt in this area and requires more time to depolarize.

#### Summary

The Philadelphia Electric Company has had excellent results in stopping lead cable sheath corrosion with duct anodes.

However, certain problems developed as listed below:

1. Graphite elements deteriorated when operating in silt, reducing the anode life to less than one-tenth of that anticipated.

2. Polyvinyl insulation and rubber insulation with neoprene jacket deteriorated rapidly when used on cable supplying direct current to graphite anodes operating in silt.

3. Polyvinyl tape lost its adhesion, resulting in failure of electrical connections.

In the design of new duct anodes, the following steps were taken to correct the above conditions:

1. Silicon iron elements were used instead of graphite.

2. Individual elements were assembled on a continuous insulated wire to eliminate all mechanical connectors, splices and taping.

3. The d-c supply cable was insulated with black high molecular weight polyethylene.

Curves derived from field data were helpful in determining the most economical anode element spacing and the minimum current requirements when cathodically protecting cables with an articulated duct anode.

#### Acknowledgment

The author gratefully acknowledges the assistance of Arch T. Flower for developing improved fabrication methods and the pressure testing of various element designs, and of co-workers L. D. Cropper, A. H. Forbes and D. L. McDonald in assembling information and criticizing the text.

#### References

1. H. L. Davis, Jr. Carbon Anode Installed Electric Cable Conduit. *Corrosion*, 11, 295t (1955) July.
2. U. S. Patent No. 2,803,603.
3. Albert L. Ayres. Discussion—Carbon Anode Installed in Electric Cable Conduit. *Corrosion*, 11, 556t (1955) Dec.
4. Final Report on Four Annual Anode Inspections—A Report of Technical Unit Committee T-2B on Anodes for Impressed Current. Publication 56-1. *Corrosion*, 12, 47t (1956) Jan.

Any discussion of this article not published above will appear in the December, 1959 issue

### DISCUSSIONS ON TECHNICAL ARTICLES ARE SOLICITED

Discussions on technical articles published in *Corrosion* will be accepted for review without invitation. Discussions must be constructive, accompanied by full substantiation of fact in the form of tables, graphs or other representative data and be submitted in three typewritten copies. In cases where illustrations are submitted, at least one copy of figures should be of a quality suitable for reproduction.

Authors will be sent on request a copy of the NACE Outline for the Preparation and Presentation of Papers.

Discussions will be reviewed by the editor of *Corrosion* and will be sent to the author of the paper discussed for his replies, if any. Publication will be in the Technical Section with full credit to the authors together with replies. Discussions to papers presented at meetings of the association may be submitted in writing at the time of presentation or later by mail to the editorial offices of *Corrosion*, 1061 M & M Bldg., Houston 2, Texas.

# Anchor Pattern Profile and Its Effect on Paint Performance\*

By JOSEPH BIGOS

## Introduction

SEVERAL PREMATURE failures of paint occurred in 1951 on blast cleaned structural steel exposed to an industrial atmosphere for less than a year. These results were surprising because the surface had been blast cleaned thoroughly and painted with high quality, heavy-duty steel primers. Examination of the specimens under magnification revealed that failures occurred by inception of pinpoint rusting on peaks of excessively rough surfaces, as shown in Figure 1. Insufficient primer obviously had been applied to the anchor pattern peaks.

Experimental work verified this conclusion. Steel plates were grit blasted in the same manner as the early failures were, and identical steel plates were sand blasted in a conventional manner. These plates were primed with a red lead phenolic paint and exposed in a salt spray cabinet. In a few days, pinpoint rusting began on the peaks of the grit-blasted specimens, but none had occurred on the sand-blasted specimens.

Research to determine the relationship between anchor pattern and paint performance was conducted by the Steel Protection Fellowship at Mellon Institute under the auspices of the Steel Structures Painting Council. Results of that investigation, conducted by the author, are the subject of this article.

## Anchor-Pattern Profile Measurement

Anchor pattern refers to the physical characteristics or surface topography which affects mechanical bond of coatings. The anchor pattern profile is an outline of the surface cross section showing actual contours so that height of the anchor pattern projections can be measured.

An illustration of an anchor pattern profile is shown in Figure 2. Maximum height of the profile is the vertical distance between the valley bottoms and top of the highest peaks. This distance is  $h_{max}$ . The distance between peaks does not enter into the value of  $h_{max}$  even though distance between peaks can have significant effects on paint performance. An example of such a surface is one that has been cleaned by rotary descalers. Profile of this surface is mostly a smooth plane with intermittent high peaks; consequently it is difficult to protect.

Generally, the anchor pattern profile is determined by an instrument which traces the surface contour with a fine point that develops an electrical current. After amplification, electrical impulses are read on a meter or are used to drive

## About the Author



JOSEPH BIGOS—Since January 1, 1957 he has been with Applied Research Laboratory, United States Steel Corp., Monroeville, Pa. as head of its organic coating section. He now works on recommendations and specifications concerning maintenance painting, research on organic coatings, production, on linings, containers and metallic coatings. He has BS, MS and PhD degrees from University of Pittsburgh. From 1946 through 1951 he taught chemical engineering at University of Pittsburgh, was a consulting chemical engineer 1949-50 and 1951-56 was senior fellow of Mellon Institute and director of research for Steel Structure Painting Council. Among other engineering groups he belongs to NACE.

a recording pen which records the profile on a chart.

The anchor pattern profile of a steel plate that has been grit blasted by a centrifugal blast cleaning machine is shown in Figure 3. This cleaning technique is the same as that used on surfaces which failed prematurely after they had been painted. Maximum height of the profile, as measured from the chart by a surface analyzer is 4 mils. Due to



Figure 1—Rusting on tips of painted peaks.

## Abstract

Techniques for examination and measurement of the anchor pattern profile of cleaned surfaces are described. Effects of various cleaning techniques on surface roughness were measured. Blast cleaning with high density, large particles produced excessively rough surfaces. Paint tests were made on steel with a wide range of anchor patterns. Concludes that height of the anchor pattern profile has a limited effect upon corrosion protection afforded by paints in atmospheric exposure. 2.3.7

the inherent nature of electrical instrument response, meters that indicate transient surface roughness during traces give a value of roughness known as the RMS roughness or root mean square roughness ( $h_{rms}$ ). This roughness figure is very low because it is the square root of the sum of the squares of the lengths of several evenly spaced lines projecting from the profile central axis to the peaks and valleys divided by the number of lines.

Because paint failure by pinpoint rusting occurs on the tips of peaks, maximum height of the anchor-pattern profile ( $h_{max}$ ) must be known. Roughness measurements such as  $h_{rms}$  are important in determining the smoothness of the painted surface and bond of the coatings, but they do not indicate the height of the tallest peaks.

Early work in this project was concerned primarily with measuring the height of the profile. Trace instruments used were (1) the Brush Surface Analyzer which included an electrical indicating instrument calibrated in  $h_{rms}$ , a chart which traced the profile curve so that  $h_{max}$  could be measured, (2) the Profilometer, which indicates and records  $h_{rms}$ .

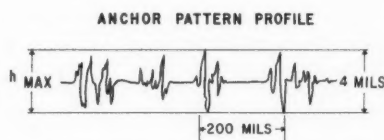


Figure 2—Maximum height of anchor pattern profile ( $h_{max}$ ).

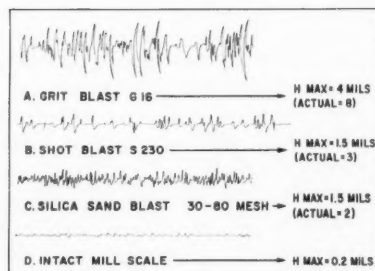


Figure 3—Typical anchor pattern profiles.

\* Submitted for publication September 8, 1958. A paper presented at the 14th Annual Conference, National Association of Corrosion Engineers, March 17-21, 1958, San Francisco, Cal.



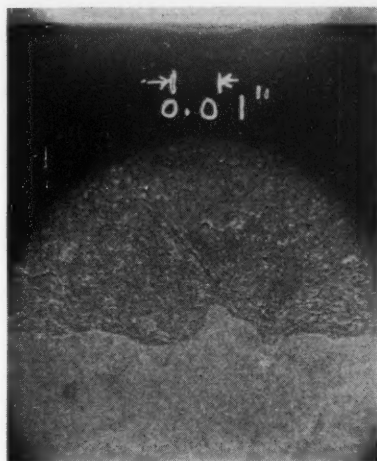


Figure 4—Cross section of G16 grit blasted steel.

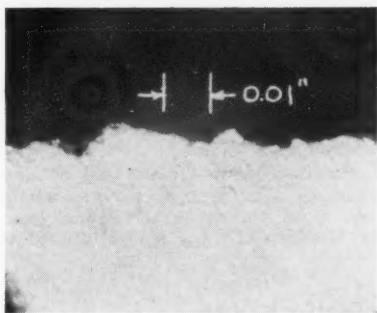


Figure 5—Cross section of G50 grit blasted steel.

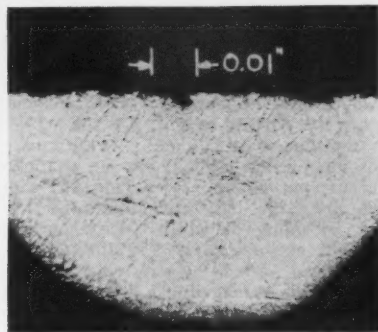


Figure 6—Cross section of sand blasted steel.

able for production or field work. Specimens may be placed in the work position in field blasting and brought into the laboratory for measurement.

1. A long flat spot about  $\frac{1}{2}$  to 1 inch wide is ground on the surface of a blast cleaned steel specimen. Grinding is continued until the bottoms of the deepest pits are just visible. Depth of the ground cut is measured from the top of the peaks with a depth micrometer. The micrometer base should be at least two inches long and should be placed across the cut; the base will rest on top of the high peaks. The depth to the nearest mil is read and estimated to the nearest tenth of a mil with a standard machinist's depth micrometer or depth micrometer calibrated to tenth of a mil.

Figure 7 shows this method applied to a specimen. The black area is the smooth, ground cut; the white specks are the pit bottoms. The blast cleaned area is shown, and the numerals shown indicate the ground cut depth is 10 mils (where the pits disappear) and 7 mils (where the pits are fairly numerous and not completely ground out). This cut was made at a slight angle. Depth measurement is made where the pit bottoms just disappear. Unusually deep pits should be neglected. This method gives the truest over-all picture of profile's maximum height.

2. Method Number One can be adapted for field use by grinding a flat spot with a portable drill and a small, cup shaped grinding stone. Again, grinding is continued until the pit bottoms disappear. It is difficult to grind a flat area in this manner; therefore depth measurement should be made on a carefully chosen spot. The micrometer rod should be thin, about  $\frac{3}{32}$ -inch.

3. The profile height is measured and recorded with a surface analyzer. This method is fast but does not accurately measure the height because of instrument limitations and stylus radius used on rough surfaces. These readings vary from the true height readings. On low profiles (about one to two mils) the surface analyzer registers about two-thirds to three-fourths of the correct height; on high profiles, the analyzer registers about half or less of the correct height. There is no correlation between analyzer readings and correct readings.

4. In sectioning and microscopic measurement, small pieces are cut from

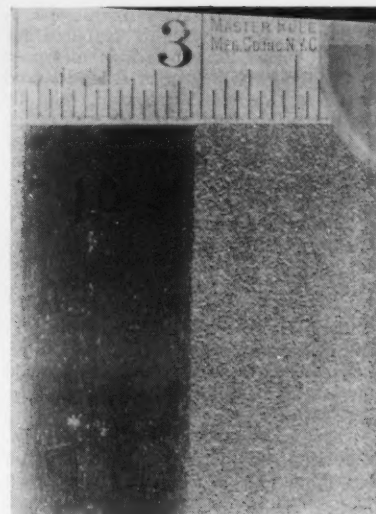
Figure 7—Determination of  $h_{max}$  by grinding surface.

TABLE 1—Comparative Profile Heights

Method	Grit Blast	Sand Blast
Proficorder	$h_{max} = 6$ mils	$h_{max} = 2$ mils
Profile...	$h_{max} = 0.30$ to	$h_{max} = 0.22$ to
Profilometer	0.69 mils	0.30 mils
Meter*		

\* Reads in microinches RMS.

TABLE 2—Comparative Measurements of Maximum Profile Height

Method	Grit Blast	Sand Blast
Vertical measure by microscope...	8 mils	3 mils
Section & microscopic measure...	10	2½
Grind & micrometer...	8	2
Brush Surface Analyzer...	4½	2

the specimen and mounted for microscopic examination of a cross section showing the surface profile. Specimens must be ground and polished according to standard metallographic practice to be sure the profile measured is not produced by the cutting method. The profile's maximum height is measured by a calibrated filar eyepiece micrometer or photomicrographed at known magnification and measured.

The probability of not sectioning through the maximum height of profile necessitates regrinding and polishing of the specimen several times so that the highest profile is revealed and recorded.

This method results in the most accurate measurement of an individual peak, but it is the most tedious and expensive. It is difficult to know if the results are truly representative of the over-all condition.

5. Vertical measurement by microscope is an accurate method and has been chosen as the easiest, quickest and most inexpensive method for general work. It agrees with Method Number One when several readings are taken to find the average of the maximum heights.

The specimen is placed on the stage

of a standard laboratory microscope. A section of the surface is searched for highest peaks. Peak height is measured by focusing on the tip of the peak and then lowering the microscope tube by the fine adjustment until the microscope is focused on the bottom of the lowest pits in the field of view. Measurement is made by reading the microns of movement on the fine adjustment dial; this is later converted to mils and recorded. Measurement is repeated three times and the average taken. If measurements are made carefully, consistent and reproducible results will be attained.

Comparison of the results of the preceding measurement methods with results on plates blast cleaned in actual operations is indicated in Table 2.

#### Abrasive Impact

The impact of the abrasive particles determines the anchor-pattern profile in blast cleaning. Impact energy depends upon particle weight and its speed. Effectiveness of the impact in cleaning the surface, or in roughing it, depends upon the angle of contact, particle shape and hardness and toughness of the particle and surface.

Because of the many unknowns involved in blast cleaning such as the cushioning effect of rebounding abrasive, it is more practical to determine cleaning rates and anchor-pattern profiles under actual operating conditions rather than attempting to theorize.

Impact energy of particles may be calculated by using the relation

$$\text{Kinetic Energy} = \frac{1}{2} mv^2 \text{ or } \frac{1}{2} \frac{wv^2}{g}$$

where  $m$  is the true mass of the particle,  $w$  is the particle weight,  $g$  is the acceleration due to gravity and  $v^2$  is the square of the particle velocity. As an example of the particle-impact energy, steel shot of size S230 has a maximum particle size of about 0.030 inch. Such a particle weighs approximately  $3.9 \times 10^{-6}$  pounds. A typical particle velocity when propelled from a centrifugal blast cleaning wheel would be 200 feet per second. The resulting impact energy available in the moving abrasive particle is easily calculated.

$$\text{Impact energy} = \frac{1}{2} \cdot \frac{3.9 \times 10^{-6} \text{ lbs}}{32.2 \text{ ft/sec}^2} \cdot (200 \text{ ft/sec})^2 = 0.0024 \text{ ft lbs.}$$

The velocity of particles impelled by centrifugal blast cleaning wheels is greater than the rim speed of the wheel. The particles theoretically have the same velocity regardless of size or mass. In nozzle blast cleaning, particles vary in speed depending upon size, density and shape though all other conditions are fixed.

Since impact energy varies with the square of the velocity, doubling particle velocity increases the energy four times. Consequently, if even a fraction of the abrasive is propelled at increased speeds, increased roughening of the surface can

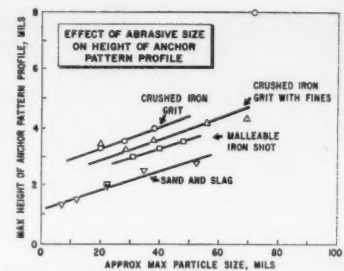


Figure 8—Anchor pattern height versus particle size.

occur. Rosenberg<sup>7</sup> measuring the velocity of No. 50 iron grit in direct pressure blast cleaning, shows that 4.56 percent

and 3.38 percent of the abrasive particles obtained speeds of 633 feet per second and 554 feet per second, respectively, though the average particle velocity was only 254 feet per second. Approximately 10 percent of the abrasive will do 4 times as much roughening of the anchor pattern as the main body of the abrasive. For this reason, maximum particle sizes should be considered when anchor-pattern profile is studied.

Because sand is widely used in blast cleaning, the effect of particle weight and speed on the anchor pattern must be considered. Silica sand is about the

TABLE 3—Abrasives, Screen Analysis and Maximum Profile Height

Plate No.	Abrasive	Screen Analysis Wt. % on U.S. Screen No.*										Max. Particle Size, Mils	Maximum Height of Profile, Mils	
		12	16	18	25	30	40	50	80	100	Pan		Brush Surface Analyzer	Vertically by Microscope
1....	Large River Sand	..	..	12.7	19.6	17.0	24.3	15.8	4.0	..	6.6	53	1.8	2.8
2....	Medium Ottawa Silica Sand #27...	..	..	..	11.4	38.3	45.6	3.8	0.6	..	0	34	1.2	2.5
3....	Crushed Slag	..	..	(estimated at minus 80 mesh)	..	..	..	..	..	..	..	7	1.1	1.3
4....	Fine Ottawa Silica Sand	..	..	..	0.5	1.8	14.2	46.5	33.2	2.6	0.7	22	1.3	1.9
5....	Iron Shot S230**	..	..	..	..	..	..	..	..	..	..	..	..	..
6....	Iron Grit G-50**	..	..	..	..	..	..	..	..	..	..	20	2.0	3.6
Not Painted	Iron Grit G-40**	..	..	..	..	..	..	..	..	..	..	28	1.7	4.3
7....	Iron Grit 10% G-50 and finer	..	..	..	0.1	0.3	14.7	32.6	35.4	9.4	7.5	20	1.2	3.4
8....	Iron Grit 10% G-40 and finer	..	..	..	0.5	3.9	17.3	30.0	31.9	8.8	7.4	28	1.2	3.2
9....	Iron Grit 10% G-25 and finer	..	..	..	4.4	4.2	18.1	28.9	30.6	7.8	5.7	38	1.3	3.6
10....	Iron Grit 10% G-16 and finer	..	11.8	..	12.8	7.9	18.8	23.6	18.6	..	6.4	55	3.4	4.3
11....	Iron Shot S-230**	..	..	..	..	..	..	..	..	..	..	31	1.4	3.0
12....	Iron Shot S-330**	..	..	..	..	..	..	..	..	..	..	40	1.6	3.3
13....	Iron Shot S-390**	..	..	..	..	..	..	..	..	..	..	48	2.1	3.6
14....	Fine Ottawa Silica Sand (1-H)	..	..	..	0.2	2.2	20.4	46.7	28.2	1.9	0.2	22	1.5	2.0
15....	Very Fine Ottawa Silica Sand	..	..	..	..	..	0.4	1.5	9.1	10.6	78.0	12	1.2	1.5
16....	Iron Grit G-14 and finer	2.7	5.6	..	4.0	3.6	13.7	24.6	28.9	..	16.8	56	3.3	4.2
17....	Iron Grit G-50**	..	..	..	..	..	..	..	..	..	..	20	2.2	3.3
18....	Iron Grit G-40**	..	..	..	..	..	..	..	..	..	..	28	1.7	3.6
19....	Iron Grit G-25**	..	..	..	..	..	..	..	..	..	..	38	2.8	4.0
20....	Iron Grit G-16	2.5	84.8	..	12.5	..	..	0.1	..	..	..	72	3.7	8.0

\* The minus sign indicates all abrasive passes through screen.

\*\* Analyses were not run on following abrasives which meet classification of SAE as follows:

#### Tolerances for Grit Numbers

Plate No. Grit No.	High Limit Screen		Nominal Screen		Low Limit Screen	
	Grit Retained, % Max.	Screen No.	Grit Retained, % Min.	Screen No.	Grit to Pass, % Max.	Screen No.
6 and 17 G-50	0	25	65	50	25	80
18 G-40	0	18	70	40	20	50
19 G-25	0	16	70	25	20	40
Tolerances for Shot Numbers						
5 and 11 S-230	0	18	70	30	20	40
12 S-330	0	16	75	20	15	50
13 S-390	0	14	75	18	15	20

TABLE 4—Blast Cleaning Rates

Run No.	Plate No.	Abrasive	Cleaning Time in Sec. for 2 sq. ft.	Rate sq. ft./min.
1	7	10% G-50 and finer	87	1.38
2	8	10% G-40 and finer	94	1.28
3	9	10% G-25 and finer	115	1.04
4	10	10% G-16 and finer	134	0.90
5	11	S-230 straight	213*	0.57
6	12	S-330 straight	168	0.72
7	13	S-390 straight	179	0.67
8	14	Silica Sand-Fine	56	2.15
9	15	Silica Sand-Very Fine	**	**
10	16	10% G-14 and finer	103	1.17
11	17	G-50 straight	77	1.56
12	18	G-40 straight	110	1.09
13	19	G-25 straight	182	0.66
14	20	G-16 straight	250	0.48

\* Ran out of shot in test and was forced to interrupt work and reload.

\*\* Sand was so fine it pulverized and work could not be observed to determine when it was clean enough to stop blasting. Results of other tests indicated fine sand cleans faster than medium or large sand, but how fine an abrasive can be used before trend reverses itself was not established.

TABLE 5—Anchor Pattern Profile Height ( $h_{max}$ ) and Resulting Paint Performance

Specimen	Abrasive	PINPOINT RUSTING ON PEAKS			
		$h_{max}$	0.5 Years	1.0 Year	3+ Years
20	G16 Crushed Iron Grit	8.0	Slight	Severe	Severe
10	10% G16 Crushed Iron Grit & Finer	4.3	Very, very slight	Very slight	Considerable
16	G14 Crushed Iron Grit	4.2	Very slight	Slight	Slight
19	G25 Crushed Iron Grit	4.0	Slight	Considerable	Considerable
13	S390 Malleable Iron Shot	3.6	None	Considerable	Slight
6	G50 Crushed Iron Grit	3.6	Very, very slight	Slight	Considerable
18	G40 Crushed Iron Grit	3.6	Very, very slight	Considerable	Considerable
9	10% G25 Crushed Iron Grit & Finer	3.6	None	None	Slight
7	10% G50 Crushed Iron Grit & Finer	3.4	None	Slight	Considerable
17	G50 Crushed Iron Grit	3.3	None	Slight	Considerable
12	S330 Malleable Iron Shot	3.3	None	Very slight	Slight
8	10% G40 Crushed Iron Grit	3.2	None	None	None
11	S230 Crushed Iron Shot	3.0	None	None	None to slight
5	S230 Crushed Iron Shot	3.0	None	None	None to slight microscopic
1	Large River Sand	2.8	None	None	None to slight microscopic
2	#27 Medium Ottawa Silica Sand	2.5	None	None	None to very slight microscopic
14	1-H Fine Ottawa Silica Sand	2.0	None	None	None*
4	Fine Ottawa Silica Sand	1.9	None	Very slight	None*
15	Very Fine Ottawa Silica Sand	1.5	None	None	None*
3	Crushed Slag	1.3	None	None	None*

\* Pinpoint rusting where phenolic primer eroded.

same shape as shot. In this experimental work, Pangborn 1-H silica sand was used, which is the same as American Foundryman's Association standard grade No. 27. This sand had an average particle velocity of 387 feet per sec<sup>1</sup> compared to 210 feet per sec for shot and 254 feet per sec for the preceding iron grit. Since these particles are about the same size, the sand will have approximately 1 1/3 times the impact energy because it has one-third the density and twice the speed of the iron shot. In experiments the maximum height of the anchor pattern profile is less for sand because of the cleavage of sand particles absorbing considerable impact energy and also due to cushioning of impact.

### Experimental Work

Steel plates used in the following work were 1/4-inch-thick hot-rolled steel plates covered with almost completely intact millscale. They were blasted by direct nozzle blasting at 80 psig air pressure with a 5/16-inch-diameter blast nozzle for all specimens except Specimens 1 to 7 which were done with a 1/8-inch diameter blast nozzle.

### Salt-Spray Test of Painted Anchor Pattern

In the preliminary test tabulated in Table 2, red lead phenolic paint (TT-P-86a, Type IV) was applied by spray. An attempt was made to measure the film thickness by using conventional instruments, but film thickness is actually an intangible item on such surfaces. By careful work, the measured film thickness (by magnetic gage) was 2.5 mils and 2.5 mils, respectively, on two sand blasted specimens and 2.0 mils and 2.5 mils respectively on two grit blasted specimens.

All specimens were weighed before and after painting. The dried film thickness was calculated as 3.1 mils and 3.4 mils, respectively, for the two sand blasted specimens, and 3.7 and 4.7 mils for the two grit blasted specimens. A heavy coat of red lead phenolic paint was spray applied to all the specimens to cover as well as could be done.

For the sand blasted specimens, no peaks were visible after painting, but hills and valleys were visible on the grit blasted specimens. From these results, it is estimated that an equivalent

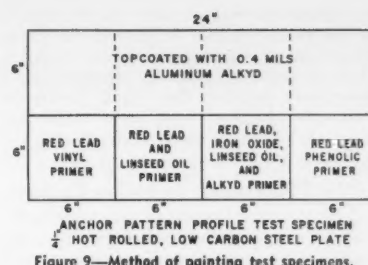


Figure 9—Method of painting test specimens.

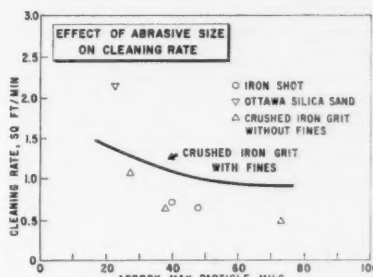


Figure 10—Cleaning rate versus particle size.

thickness of 0.75 mils is used to fill the sand blasted anchor pattern and that an equivalent thickness of 2.0 mils is used to fill the rougher grit blasted patterns.

### Cleaning Rates

An attempt was made to produce a synthetic grit-size distribution that would correspond to the distribution in plant practice. This distribution is caused by attrition of the abrasive and make-up with a larger size.

In these tests, a pulverized G-50 abrasive, which had been used previously, was the basis for the finer abrasive. A mixture was made with 10 percent new G-50 and 90 percent finer. After this mixture was used once, a new mixture was made with 10 percent new G-40 and 90 percent G-50 and finer. In this way, abrasives were selected which would correspond to actual plant operations where G-14, G-16, G-25, G-40 and G-50 abrasives are used. Analysis of the mixed grits is given in Table 3. "G" refers to crushed iron grit and "S" to malleable iron shot.

Cleaning rates given in Table 4 were measured on 12-inch by 24-inch by 1/4-inch hot-rolled plates with almost intact millscale when direct air pressure blasted using a 5/16-inch nozzle and 80 psig air pressure on the tank.

### Particle Size vs Maximum Height

The average maximum height of profile increased with increasing average particle diameter for a given type and density of particle. For crushed cast iron grit, shot and light abrasives (such as sand and crushed slag) there is a separate relationship between profile depth and average particle size or maximum particle size: crushed grit cuts the deepest profile, shot is next and the smallest profile is cut by light abrasives. Test results on 21 specimens are tabulated in Table 3 and shown graphically in Figure 8. Some of these results have been published by Liebman<sup>1</sup> and Bigos<sup>2</sup>. Plates 6



by 6-inch by 1/4-inch were blast cleaned to determine profile heights at the same time that 12 by 24-inch specimens were blast cleaned. The 12- by 24-inch specimens were painted; the 6-inch specimens were not painted and were used for physical measurements and zeroing of magnetic paint film thickness gages.

#### Paint Performance vs Anchor Pattern

The main evaluation of paint performance as a function of anchor pattern consisted of painting large specimens and exposing them in an industrial atmosphere. Figure 9 shows the method of painting the blast cleaned 12 by 24-inch specimens.

Four primers were used: red lead vinyl per U. S. Bureau Ships Formula 119; red lead and linseed oil per TT-P-86a, Type I; red lead, iron oxide, linseed oil and alkyd, per TT-P-86a, Type II; and extended red lead phenolic paint per TT-P-86a, Type IV. Primers were applied by spray. After several days of drying, the top half of each specimen was brush painted with a thin coat of aluminum alkyd paint.

The primers were applied in a manner to give a full wet coat over the anchor pattern. Dry film thickness was measured as well as possible with a magnetic film thickness gage after zeroing on the similar unpainted 6 by 6-inch specimen. There was a significant effect of anchor pattern profile on the reading of the gages because of a variation in magnetic permeability caused by air gaps in the anchor pattern. The roughest anchor patterns,  $h_{max} = 8$  mils, changed the zero point by +1.25 mils for one gage and by +1.5 mils for another gage when the gages were zeroed on a smooth ground 1/4-inch thick plate. Fine anchor patterns had a much smaller shift.

Twenty specimens were painted, each with four primers for a total of 80 primed areas. Of these, 59 had a measured dry film thickness of 1.0 to 1.25 mils; four had a film thickness of 0.9 mils and one at 1.5 mils. The mean dry film thickness was 1.14 mils. The topcoats were uniform and had a mean value of 0.40 mils. All painted specimens were exposed to the South on the roof of Mellon Institute in the industrial atmosphere of Pittsburgh, Pa., on April 2, 1952, at an angle from the horizontal of about 20 degrees.

Paint test results are shown in Table 5. The rust was difficult to find and required microscopic examination and chemical tests to identify the rust design-

TABLE 6—Effect of Anchor Pattern Profile on Paint Performance

Height of Anchor Pattern Profile, Mils	RUSTING ON PEAKS		
	Six-Month Exposure	One-Year Exposure	Three-Year Exposure
4.0 to 8.0.....	Very, very slight to slight	Slight to bad	Slight to severe
3.6.....	None to very, very slight	None to considerable	Slight to considerable
3.2 to 3.4.....	None	None to slight	None to considerable
2.5 to 3.0.....	None	None	None to slight
1.3 to 2.0.....	None	None	None

nated as pinpoint rusting. Thus, even a rating of "considerable" indicates extremely slight rusting.

#### Discussion of Results

The maximum particle sizes given in Table 3 are only approximations. They were determined by estimating the average size of 10 percent of the largest particles as well as could be done from screen analyses or tolerance limits. Crushed iron grit resulted in the highest anchor patterns because of its sharp edges and density. Peaks raised from the surface by flow of metal during the impact. Shot caused a round indentation in the surface and embeds some of the fractured millscale in the surface; this embedded millscale had no apparent effect on paint performance.

Peaks formed around the edges of the craters and where two craters overlapped a small peak. Sand tended to leave most of the original steel surface—not the millscale—because it was a cutting action, but even sand creates some peaks due to the flow of steel. Of the abrasives tested, the large crushed iron abrasives were the worst for paint performance because needle-like peaks formed.

A correlation of anchor pattern with cleaning rate for the different types of abrasives was observed. As shown in Figure 10, the particles resulting in the highest anchor pattern profile had the lowest cleaning rates. (Cleaning rate is a function of the average particle size, but maximum size was used for comparison with profile.) Fine abrasives increased the cleaning rates drastically, but extremely fine abrasives cushioned the particles and cleaning rates fall off. In a commercial trial of small crushed iron abrasives, cleaning rates were tripled over those with the large G-16 abrasive, but the small particles did not have sufficient impact to quickly remove weld flux slag. A compromise was reached by a mixture of G-25 abrasive with much finer material.

The exposure of the painted specimens did not agree with expectations that anchor pattern profile would significantly affect paint performance. No rusting occurred on the topcoated specimens even after three years' exposure except for an occasional isolated peak on the highest anchor patterns. General condition of the areas painted with primer only was good. Red lead phenolic was the only primer showing breakdown; it had eroded away to the point where the films were quite thin. With the exception of the highest anchor pattern from straight G-16 grit, rust was difficult to detect (with the exception of the red lead phenolic). Even the red lead phenolic primer showed no rusting when it was topcoated.

#### Conclusions

The results of the atmospheric paint test are summarized in Table 6. With the exception of the 8-mil anchor pattern, all of these primed panels would have an ASTM D610-43 rust rating of greater than 9.5. Based upon this experimental work, anchor pattern profile below 4.0 mils in height has insignificant effect on paint performance in atmospheric exposure when as little as 1.5 mils (dry) paint are applied. With the conventional thickness of maintenance paints, only the very roughest anchor patterns would cause failure.

No evidence or justification was found for the rule that paint thickness should be three times the anchor pattern height. Instead, about one mil equivalent of dry film thickness should be allowed to fill normal anchor patterns over the thickness of paint known to give paint protection desired on smooth steel.

#### References

1. W. A. Rosenberger. Impact Cleaning. Penton Publishing Co., Cleveland, 1939.
2. A. J. Lieberman. Surface Protection Against Wear and Corrosion. American Society for Metals, Cleveland, 1954.
3. J. Bigos. Steel Structures Painting Manual, Vol. 1 and 2. Steel Structures Painting Council, Pittsburgh, Pa., 1954 and 1955.

Any discussion of this article not published above will appear in the December, 1959 issue

CORROSION  
two  
rosion  
corrosion  
hem to  
it may  
severity  
that co  
chloride  
per ma  
tion, b  
is suffi  
is no c  
corrode  
Local  
usually  
forms c  
and cra  
a large  
tially u  
in that  
metal.  
may be  
failed.  
The an  
measur  
sudden  
of cor  
tigue a

Stress  
nearly  
steel an  
alloys,  
alloys.  
Perhaps  
reputat  
metals,  
brass h  
steel w  
and ma  
periodic  
metals  
of cate  
in this  
A gr  
corrosi  
theories  
it. It  
underst  
scientis  
about h  
practic  
crackin  
method  
knowle  
Obvi  
the res  
factors  
might  
for alt

★ Submi  
paper  
Region  
of Co  
Janua

# Probability As Related to Stress Corrosion Cracking of Copper Alloys\*

By D. H. THOMPSON

## Introduction

CORROSION CAN be divided into two broad categories—uniform corrosion and localized corrosion. Uniform corrosion is not generally a major problem to corrosion engineers, not because it may not be severe, but because its severity is fairly predictable. The fact that copper corrodes uniformly in ferric chloride solution does not mean that copper may be used for handling the solution, but merely that the corrosion rate is sufficiently predictable so that there is no doubt that copper is too rapidly corroded.

Localized corrosion is full of surprises, usually unpleasant ones. The commonest forms of localized corrosion are pitting and cracking. It is of little moment that a large area of metal surface is essentially untouched by corrosion, if there is in that area a pit that perforates the metal. The total amount of corrosion may be very small, but the piece has failed. Cracking may be even worse. The amount of corrosion may be immeasurably small, but failure occurs suddenly and catastrophically. Two types of corrosion cracking are corrosion fatigue and stress corrosion cracking.

## Stress Corrosion Cracking

Stress corrosion cracking occurs in nearly all types of metals. It happens in steel and in stainless steel, in aluminum alloys, in magnesium alloys, even in gold alloys. It occurs also in copper alloys. Perhaps the copper alloys have a worse reputation in this respect than the other metals, because the season cracking of brass had been observed before stainless steel was invented and when aluminum and magnesium were just squares on the periodic chart of the elements. The other metals have done a fairly creditable job of catching up with the copper alloys in this respect, however.

A great deal is known about stress corrosion cracking and several excellent theories have been proposed to explain it. It is not considered to be entirely understood, however, and certainly the scientists have not stopped thinking about how and why it occurs. From the practical standpoint, stress corrosion cracking is very well understood. The methods of prevention are common knowledge.

Obviously, stress corrosion cracking is the result of two simultaneously acting factors—stress and corrosion. To these might be added a third factor—time, for although stress corrosion cracking



About the Author

D. H. THOMPSON is with Corrosion Research Laboratory, The American Brass Company, Waterbury, Conn. He has published papers on atmospheric corrosion and stress-corrosion cracking of copper and copper-base alloys. He received BS degree from Yale in 1933.

usually becomes manifest as a sudden failure, this follows first an incubation period and then a period during which crack propagation takes place. Stress may be residual or applied. Residual stress is that stress that is left in the metal from prior cold work or deformation of one sort or another. Applied stress is the stress resulting from and existing during the application of a load. Either type of stress may cause stress-corrosion cracking but only if the stress is tensile. Compressive stresses not only do not cause stress-corrosion cracking but surface compressive stresses tend to prevent it, even though tensile stresses exist in the body of the metal.

The corrodents that cause stress corrosion cracking are of considerable interest. Each alloy system tends to be specific, to have only one corrodent that will crack it. The copper alloys are quite exclusive about this. Their Achilles heel is ammonia. Under some conditions, liquid metals also will crack the copper alloys, but the mechanism is different and the practical importance is different. It may be stated that ammonia is required to cause the stress corrosion cracking of copper alloys, but if the statement is challenged it is necessary to hedge and to fall back on the generalization, "It is generally believed that ammonia is necessary for the stress corrosion cracking of copper alloys." Actually the matter cannot be easily proved. If, for instance, stress corrosion cracking should occur in an atmosphere high in carbon dioxide, it would be easy to assume that the carbon dioxide caused the cracking, but difficult to prove that this was so and that ammonia was indeed absent from the atmosphere.

The real reason for believing that ammonia is responsible is that ammonia

## Abstract

Factors determining the probability of stress corrosion cracking of copper alloys are concentration of ammonia present, concentration of water, concentration of air, stress level and susceptibility of particular alloy to stress corrosion cracking. In case histories discussed the contribution of each of these factors is evaluated. Specific cases considered include failure of red-brass pipe, cold-drawn copper water tubing, 70-30 cupro-nickel tubing, Admiralty and aluminum brass condenser tubes, and yellow brass screw shells. The relative resistance of 10 copper alloys to stress corrosion cracking is listed. The role of ammonia in causing stress corrosion cracking of copper alloys is considered in detail. 3.2.2

causes cracking so rapidly. A test was conducted in which highly stressed brass parts were hung in covered containers. Each container had a quantity of water in the bottom. The water in each of four different containers was saturated with a different gas—carbon dioxide, sulfur dioxide, hydrogen sulfide, and ammonia. Within 16 hours the three specimens above the ammonia solution had cracked. At the end of nine months, one specimen that was exposed above the hydrogen sulfide solution cracked. At the end of two years, no other specimen had cracked. It may be that the hydrogen sulfide did cause stress corrosion cracking, or the atmosphere in the container may have been contaminated with ammonia. In any event, ammonia caused cracking at least 400 times as fast as the other gases.

Ammonia alone is not a sufficient corrodent. As in most other types of room-temperature corrosion, water and air are necessary ingredients. As far as copper alloys are concerned, cracking is more rapid in a gaseous environment—moist ammoniacal atmosphere.

The conditions for the occurrence of stress corrosion cracking of copper alloys have been described. The metal must be under a tensile stress. It must be in contact with a corrodent containing ammonia, moisture, and air. Sufficient time must be allowed for cracking to occur and the metal must be an alloy that is susceptible to stress corrosion cracking. The time may vary over many orders of magnitude. Cracking may occur in as little as five minutes or it may be delayed for months, even for years.

## Applications of Probability

Currently, nearly everything in science and engineering is expressed as a probability. If an object is dropped, it will fall to the ground. It might be more correct to say that if something is dropped there is a high probability that it will fall to the ground. Probability has some usefulness in describing why cracking does or does not take place. If there is a probability of an event

\* Submitted for publication January 26, 1959. A paper presented at a meeting of the Canadian Region, Eastern Division, National Association of Corrosion Engineers, Montreal, Quebec, January 12-14, 1959.

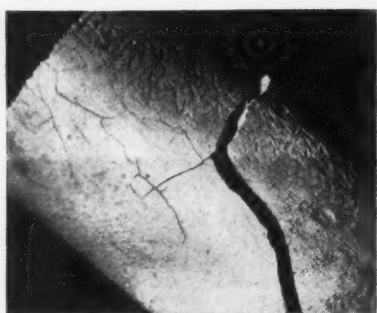


Figure 1—Red-brass pipe. Note cracks in outer surface. 1.8X.

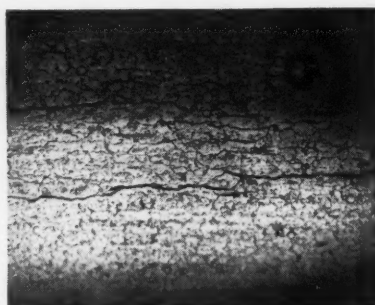


Figure 3—Phosphorized copper tube. Cracks are shown in outer surface.



Figure 4—Longitudinal section through crack in phosphorized copper tube. 100X.

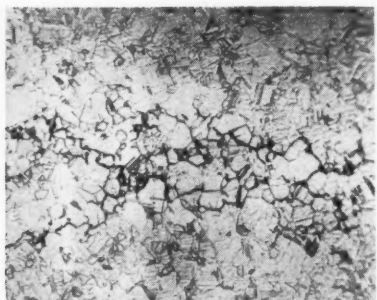


Figure 2—Longitudinal section through intergranular crack in red-brass pipe. 125X.

occurring and another probability of another event occurring, the probability that both will occur is the product of the two probabilities.

Here is a simple example from the field of engineering. A pressure vessel, in which there is a hand hole, is to be designed. The cover for this hole is to be secured with four bolts. The bolts are produced to a certain tensile strength, but to prove that any particular bolt meets the specification it is necessary to make a destructive test, and then the bolt is not available for use. Consequently, inspection is carried out by a sampling procedure, a certain proportion of the bolts is tested and there is a known probability that any particular bolt will have adequate tensile strength. If the probability is 0.99, then the probability that any bolt will not meet the specification is 0.01 or 1 in 100. What then is the probability that two of the bolts, chosen at random, will not have the required strength? It is the product of the two probabilities or 1 in 10,000. For three bolts it is 1 in 1,000,000 and for four, one in 100,000,000. So it can be concluded that the probability that the hand-hole cover will blow off because of failure of the four bolts is 1 in 100,000,000.

The probability of the occurrence of stress corrosion cracking may be similarly considered. The factors that favor stress corrosion cracking of copper alloys are, as has been said—ammonia, moisture, air, stress, and a susceptible alloy. If each of these is present to a high degree, which is equivalent to saying that its probability is high, then the probability of cracking will be high. This

can be expressed mathematically, as follows:

$$\frac{1}{T} = (\text{NH}_3) (\text{H}_2\text{O}) (\text{Air}) (\text{S}) (\text{Alloy})$$

where

(T) is the time before cracking occurs

(NH<sub>3</sub>) is ammonia concentration

(H<sub>2</sub>O) is water concentration

(Air) is air concentration

(S) is stress level

(Alloy) indicates an alloy that is susceptible to stress corrosion cracking.

These can be expressed as probabilities, (NH<sub>3</sub>) may be taken as the probability that a high concentration of ammonia exists. The formula may be written:

$$P_c = P_{\text{NH}_3} \cdot P_{\text{H}_2\text{O}} \cdot P_{\text{Air}} \cdot P_S \cdot P_{\text{Alloy}}$$

where

P<sub>c</sub> is the probability that cracking will occur.

#### Failure of Red-Brass Pipe

Here is an example of an unpredicted case of stress corrosion cracking. Red Brass 85-15 has good resistance to stress corrosion cracking. Accordingly, annealed red-brass pipe would not be expected to stress corrosion crack in a plumbing installation. Air and moisture may be present, but not much ammonia. It was unusual, then, to receive a complaint of stress corrosion cracking of red-brass pipe. Examination revealed the following facts:

1. The plumber had bent the pipe during installation and this had produced residual stresses.

2. The pipe had been lagged with animal hair felt and had been installed in the crawl space beneath a summer cottage. The nitrogenous material in the felt decomposed to form ammonia.

3. No adequate vapor barrier had been provided either next to the pipe or outside the lagging.

With enough ammonia, moisture, air, and stress to increase the probability of cracking, the low probability due to the nature of the alloy was overcome and failure occurred. Figure 1 shows the outer surface of the cracked tube while Figure 2 shows a magnified longi-

tudinal section. Note the intergranular path of the crack.

#### Failure of Copper Water Tubing

Another case was even more unusual although it was quite similar. Phosphorized copper has excellent resistance to stress corrosion cracking. Cold-drawn copper water tube is a standard brass mill product. The resistance of the alloy to stress corrosion cracking is so good that no concern is felt about the internal stress that results from cold drawing. Indeed the stress is not likely to be high because of the mechanical properties of the metal.

The tube in question was installed in a tunnel. It was lagged with animal hair felt. There was an adequate vapor barrier outside the felt lagging. All the probabilities, except stress, were low. But in some way that has never been explained, part of the lagging got wet. Perhaps it occurred during installation. In any event, decomposition of the nitrogenous material in the felt formed ammonia, enough to create a strong odor. The probabilities were all changed—ammonia, moisture, air, stress—everything but the susceptibility of the alloy now favored stress corrosion cracking and they prevailed over the resistance of the alloy. Figure 3 shows the cracked tube; Figure 4 is a longitudinal section through a crack. The deductions concerning the reasons for the failure of this tube are substantiated by the fact that only where the lagging was wet did cracking occur. Elsewhere the tube was found to be bright and clean when the covering was removed. These two examples point to the necessity for expecting the unexpected when designing to avoid stress corrosion cracking.

#### Failure of 70-30 Cupro Nickel

Here is an example of a different type. Cupro nickel-30 per cent has excellent resistance to stress corrosion cracking. From experience with service failures, it can almost be said to be immune to stress corrosion cracking. For some laboratory tests, a 70-30 cupro-nickel tube was severely sunk (i.e., drawn without a plug). This treatment causes



extremely high tensile stresses in the outside surface. Several feet of this tube was stored in a cupboard in the laboratory. After a relatively short time (nine months) the tube was found to be cracked from end to end. All the probabilities favoring stress corrosion cracking, except two, were low. The tube was nominally dry. There was doubtless some ammonia in the laboratory atmosphere, but it was never extremely great. In fact during an appreciable part of the storage period the plant was closed by a strike and the laboratory was not in use.

The only logical conclusion is that in this tube the stress was so excessively high that this offset the lack of corrosion and the excellent resistance of the tube to cracking. Again it can be considered that the probability of failure was the product of the several probabilities associated with the factors that accelerate cracking. Figure 5 is a cross-section through a crack in the tube.

### Condenser Tubes

Although it is practically impossible to write down numbers that represent the probabilities, the idea of probability is frequently inherent in the selection of an alloy for a specific purpose. Condenser tubes, those used in conventional shell-and-tube condensers such as in steam stations, do not frequently fail by stress corrosion cracking. The few failures represent an extremely small percentage of the great number of tubes in service.

Two of the common condenser tube alloys, Admiralty and aluminum brass, have poor resistance to stress corrosion cracking. They are constantly wet by condensing steam. Because of the use of ammonia or amines, added to boiler feed water to reduce ferrous metal corrosion, the ammonia concentration may be appreciable. Of the five factors, three are high. Stress is designed to be low. Annealed tubes are used, but installation and service stresses may be greater than are anticipated. There may be vibration that causes cyclic bending stresses resulting in stress corrosion-fatigue cracking. Stresses may be set up by the rolling-in of the tubes. Sometimes the rolling in of tubes is extended beyond the inner edge of the tube sheet resulting in a bulge that has internal stress. Accidental denting or bending of tubes during handling may also produce stresses.

The fifth factor is air and this may be virtually absent in much of the condenser. The fact that absence of air is a usual deterrent to stress corrosion cracking in condensers and heat exchangers has been demonstrated by service failures. An oil refinery was closed by a strike. One of the heat exchangers was drained and stood empty for some time. At the end of the strike it was found that tubes had failed by stress corrosion cracking, not just a few but a substantial porportion of them. In another case, tube bundles were removed from heat exchangers and stored outdoors. Corrosion products on the outside of the tubes contained ammonium salts; the air was humid. Stress corrosion

cracking of a large number of tubes ensued. It was found, however, that if the tubes were cleaned of corrosion products immediately after removal from the heat exchanger they did not crack under the same conditions. In service, the tubes did not crack because of the absence of air; in outdoor storage they did not crack if ammonia were substantially absent. One low probability was exchanged for another.

A leaking condenser tube can be serious. It will allow cooling water, which may be sea water, to get into the condensate, which will become boiler feed. Sea water is not a welcome constituent in boiler water. The condenser then has to be taken off the line, emptied, opened, the leaking tube found and plugged. It would seem, then, that every effort would be taken to avoid the possibility of stress corrosion cracking of condenser tubes. One very effective method would be the use of 70-30 cupro-nickel tubes. Here is where the probability comes in. The probability of cracking failure, with Admiralty or aluminum brass, is so low that the cost of cupro-nickel tubes is not justified.

### Screw Shell Failure

Another example that shows the probability nature of stress corrosion cracking occurred in a plant that made screw shells such as form the bases of electric lamps or are used in plug fuses. After forming, these shells have enormous internal stresses and they are made of yellow brass, an alloy highly susceptible to stress corrosion cracking. As soon as the shells are formed, they are relief annealed to rid them of the internal stresses and thus to improve their resistance to stress corrosion cracking in service. In this particular plant the annealing furnace was in a separate building from the presses. The shells had to be trucked from one building, outdoors, and into the other. Shells produced Friday afternoon were trucked to the furnace room where they were stored until Monday morning before being annealed. Normally no ill effects were experienced from this procedure, but one Monday morning it was found that thousands of shells had cracked. Not all the shells cracked, but a great many did. Three of the factors were highly probable—stress, air, and susceptible alloy. Probably failure resulted because either in transit from the presses to the furnace room, or in storage during the week end, the shells were subject to a temperature change and cool shells came in contact with warm moist air, condensation of moisture occurred. With all the other probabilities high, not much ammonia was needed to cause cracking.

In some applications a stress corrosion cracking failure may result in the loss of human life. It is then imperative that every effort be made to avoid cracking. A case that fortunately did not result in tragedy, will serve as an example. This was a track for a painter's trolley on a concrete chimney. The track was installed at the top of the chimney and was designed to support a bosun's chair

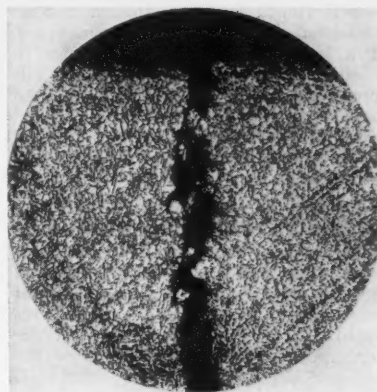


Figure 5—Cross section through crack in cupro-nickel-30 percent tube. 50X.

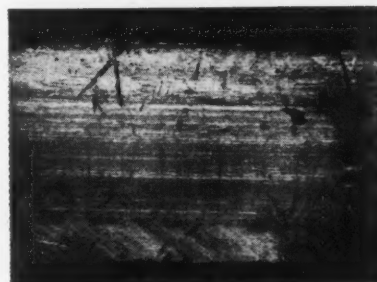


Figure 6—Naval brass painters' trolley. 4X.

so that it could be moved around the chimney easily. Naval brass was used for the track. This material has poor resistance to stress corrosion cracking. Fortunately, cracks in the track were discovered before it was used. A view of the track is shown in Figure 6.

### Effect of Annealing

An effort has been made to indicate how to predict the probability of stress corrosion cracking of copper alloys in designing or to explain stress corrosion cracking that has occurred in service. Mention should be made of which of the factors can be modified most readily to reduce the probability of stress corrosion cracking. Most frequently the effort is to reduce residual stress to a safe level, by annealing or relief annealing.

Annealing here refers to an anneal at a sufficiently high temperature to recrystallize the metal. Relief annealing is carried out at such a temperature that residual stresses will be relieved, but the metal will not recrystallize and will not be softened. To achieve both these objectives, relief of stress and retention of hardness, requires precise temperature control. The correct temperature is different for each case and depends on the alloy, the degree of cold work, and the dimensions of the piece. For yellow brass it is in the neighborhood of 300 C (572 F).

In many instances, such as the lamp bases mentioned earlier, relief annealing

is performed. In some applications an occasional failure is of no importance. If a lamp base should crack once in a while, no great economic loss is suffered. It is not worthwhile to use an expensive alloy to avoid an occasional failure but it is worthwhile to anneal the bases in order to avoid a great many failures.

There are some things that cannot be relief annealed. The brass bases of shot-gun shells are crimped to the cardboard cylinders. Stress results from this operation but the metal cannot be relief annealed without scorching the cardboard. Ammonia may result from the decomposition of smokeless powder in the shell. In the past, a few stress corrosion cracking failures occurred upon firing. Considerable research was done on how to reduce this probability at minimum cost. A change of alloy was too expensive. Waxing or lacquering were found to be effective but they also added to the cost of the shells. The problem was satisfactorily solved by careful control of ready-to-finish annealing temperature to achieve a fine uniform grain size and modifying the die design so as to stress the metal as uniformly as possible.

### Resistance of Alloy

The next most common method of avoiding stress corrosion cracking is by the choice of a resistant alloy. The differing resistance of the several copper alloys to stress corrosion cracking has been mentioned. They may be roughly classified as follows:

1. Low resistance
  - a. Brass containing over 20 per cent zinc.
  - b. Brass containing over 20 per cent zinc and small amounts of lead, tin, or aluminum such as leaded high brass, naval brass, Admiralty, and aluminum brass.
2. Intermediate resistance
  - a. Brasses containing less than 20 per cent zinc, such as red brass, commercial bronze, and gilding.
  - b. Aluminum bronze
  - c. Nickel silver
  - d. Phosphor bronze
3. High resistance
  - a. Silicon bronze
  - b. Phosphorized copper
4. Very high resistance
  - a. Cupro nickel
  - b. Tough-pitch copper

Endeavoring to keep the corrosives, air, moisture, and ammonia from the metal is the least successful way of avoiding stress corrosion cracking. Ammonia is the sneaky member of this trio. Frequently, in studying the cause of a failure, a vain search is made for the source of ammonia that has caused stress corrosion cracking, or the statement made that ammonia was not responsible for cracking because no ammonia was present. It now seems obvious that no atmosphere is free of ammonia unless it is deliberately made so under laboratory conditions. Not only does stress corrosion cracking occur both indoors and outdoors in industrial environments but also in rural and marine atmospheres. Most surprising is that it occurs in homes, not only in kitchens and bathrooms where the humidity is high and ammonia is still occasionally used for cleaning, but also in living rooms.

Stress corrosion cracking of copper alloys is not of major importance in the sense that it causes great economic loss. The practical aspects of the subject are too well understood for that. It is an interesting subject for study, first because of the dramatic nature of the failures and second because the complete understanding of the mechanism is so elusive.

**Any discussion of this article not published above  
will appear in the December, 1959 issue**

# Stress Corrosion Cracking of Oil Country Tubular Goods\*

By R. L. McGLASSON and W. D. GREATHOUSE

## Introduction

**S**TRESS CORROSION cracking is a brittle (non-yielding) metals failure mechanism in which cracks rapidly propagate to complete failure under the combined influence of stress and corrosion.

Since macroscale yielding of the metal is not essential to this mechanism, failures frequently are experienced where the metal member is under average loads well below the yield strength of the metal. The phenomenon is restricted to specific metal environment combinations.<sup>1</sup>

Prevention of such failures demands that one or more of the following approaches be used:

1. Selection of a material not susceptible to the problem in the corroding environment.

2. Use of susceptible materials below strength (hardness) levels and below applied stresses at which cracking can occur.

3. Change of environment.

Solution of the problem for oil production tubing by the first and third approaches is partially eliminated. In production environments containing hydrogen sulfide, all types of steels tested to date are susceptible to cracking.

The environment is the produced fluids over which there is no compositional control. One approach to the problem could be changing the environment with corrosion inhibitors. This approach has been poorly investigated and is not attractive from theoretical considerations.

The second approach then seems most likely to provide useful information. First, the environmental condition must be determined which causes the cracking problem. Then, to get the most service from the materials available, hardness and applied stress limits for cracking need to be established. Thirdly, the materials that can be used should be studied with compositional and heat treatment variations to determine the optimum for best performance.

Previous investigations have shown that hydrogen sulfide is the significant environmental constituent causing sulfide corrosion cracking. Hardness-applied stress limits for sulfide cracking for the variety of available API and non-API tubular goods have been determined only partially. Limited work has been done to evaluate new compositional heat-treatment combinations. This article reports

## Abstract

Stress corrosion cracking as encountered in oil production is discussed as two problems: sulfide corrosion cracking and sweet corrosion cracking. Brief review of the literature is included.

A new test method is given which uses a notched ring loaded to different percentages of yield deformation. Also includes simple polished beam specimen test methods. Tabular data is given on hardness, applied stress and time-to-failure obtained in a saturated H<sub>2</sub>S-brine system using J-55 and N-80 steels. Concludes that any steel will suffer sulfide corrosion cracking above given hardness limits and that these limits depend on applied stress.

Tests to reproduce failures in sweet systems are reported. Conclusion is drawn that sweet cracking failures are sulfide cracking at low H<sub>2</sub>S concentrations and that time-to-failure is an inverse function of the H<sub>2</sub>S concentration.

3.22

studies directed toward further information on these two points.

The sweet corrosion cracking problem is still in the stage of determining the significant components of the environments that are causing the cracking. None of the sweet environments (NaCl, CO<sub>2</sub>, acetic acid, thread compounds, etc.) studied in the laboratory have produced these failures. Studies reported were directed toward determining if sulfide is found in these sweet systems and what limiting quantities of sulfide are necessary to cause cracking.

## Test Methods Used

### Polished Beam Specimens

In tests performed by Fraser and Treseder, polished beam specimens were stressed to a calculated 120,000 psi maximum fiber stress which was above the yield stress of the material.<sup>2</sup> In another series of tests, polished beams containing holes as stress raisers were loaded to different strains and the strain for 50 percent failure noted. These strains often were above the yield strain of the material.<sup>3</sup> Statistical methods must be used to evaluate the results with this latter test. Use of this test on large numbers of steel samples have established relative cracking susceptibility data for different materials.<sup>4</sup> This data, as published, cannot be used to establish hardness-applied stress limits for failure.

Application of statistical analysis to the effects of different variables on cracking susceptibility of low chemistry steels has indicated directions in which further studies should be made. Table 1 lists some of these variables and their effect on susceptibility. Quenched and tempered low chemistry steels appear superior to normalized high chemistry steels.

Studies made by Vollmer and co-workers established some applied stress data for cracking. Simple polished beam specimens with a cold-worked pre-stress



McGlasson



Greathouse

R. L. McGLASSON is a metallurgist in the Materials Section of Production Research of Continental Oil Co. His work deals with corrosion metallurgy. He was employed formerly by Boeing Airplane Co., Wichita, Kan. He has a BS in physics and mathematics from Northwestern State College, Alva, Okla.

W. D. GREATHOUSE is supervisor of the Materials Section, Production Research Division, Continental Oil Co., Ponca City, Okla. He is co-author of several papers on petroleum production corrosion problems, has a BS in chemical engineering from Texas Technological College and is a member of NACE and AIME.

and a sub-yield applied load were used to demonstrate that with a given amount of pre-stress there are minimum applied stress limits below which failures will not occur.

The polished beam test has given considerable useful information and is satisfactory for evaluating relative cracking susceptibility of materials, particularly if stress raisers are incorporated. This test has some objectionable features which make its use for determining hardness-applied stress limits difficult, if not impossible.

### Notched Ring Specimens

The stress corrosion cracking specimen used in most of the studies reported in this article was a notched ring shown in Figure 1. The specimen was made of the material and in the heat-treatment condition to be studied.

Stress was applied to the ring by tightening the bolt. Bolt ends were fitted with rubber O-rings. Amount of stress applied was determined by deformation measurements made at the gap to 0.01-inch accuracy. The applied deformation was related to the yield strength by use of a modified Phillips C-ring test made on the same material.<sup>4</sup>

For a given test, cracking rings were loaded to different percentages of the yield point on the C-ring load-strain

\* Submitted for publication January 8, 1959. A paper presented at a meeting of the 15th Annual Conference, National Association of Corrosion Engineers, Chicago, March 16-20, 1959.



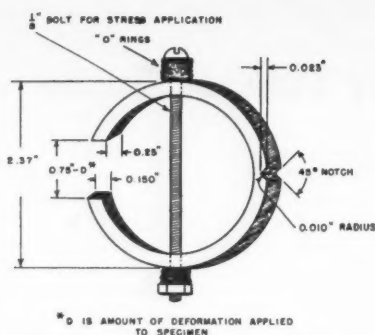


Figure 1—Notched rings used in studies of stress corrosion cracking. This specimen has shown that cracking failures do occur at below yield loads when notches are present.

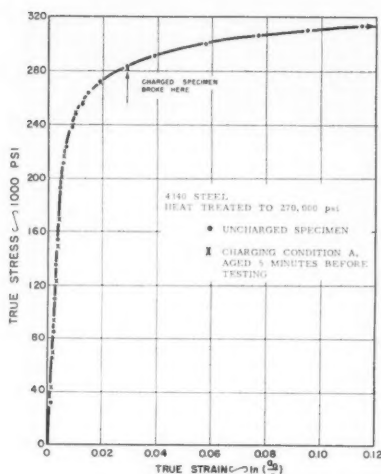


Figure 3—Initial portion of true stress—true strain curve for A1514340 specimens charged with hydrogen and uncharged with hydrogen. Artificial cathodic charging was used.<sup>10</sup>

curve. The point of linearity departure on this curve is taken as the yield point. The strain portion of the curve is magnified 10 times.

For the tests reported here, rings were deformed to 100 percent, 80 percent, 60 percent, 40 percent, 20 percent, and 10 percent of the yield deformation for any given test. Rings deformed to the 20 and 10 percent levels did not fail in a one-year test; consequently usefulness of these low load tests was questionable.

This test method was designed for the following functions: (1) Provide notch effects in test evaluations. (2) Give more reproducible hardness-applied stress results. (3) Provide reproducible sub-yield stress failure data without introducing macroscale cold-working prestresses or test loads.

As a test of reproducibility, four rings of N-80 material, oil quenched and tempered to a hardness of RC 33 to 35, were stressed to the six percentage levels given above. The rings then were immersed in a 5 percent NaCl solution continuously saturated with H<sub>2</sub>S. The 5 percent NaCl was swept of air with H<sub>2</sub>S for 24 hours before the test was started. Iodimetric titration at the end of the test showed

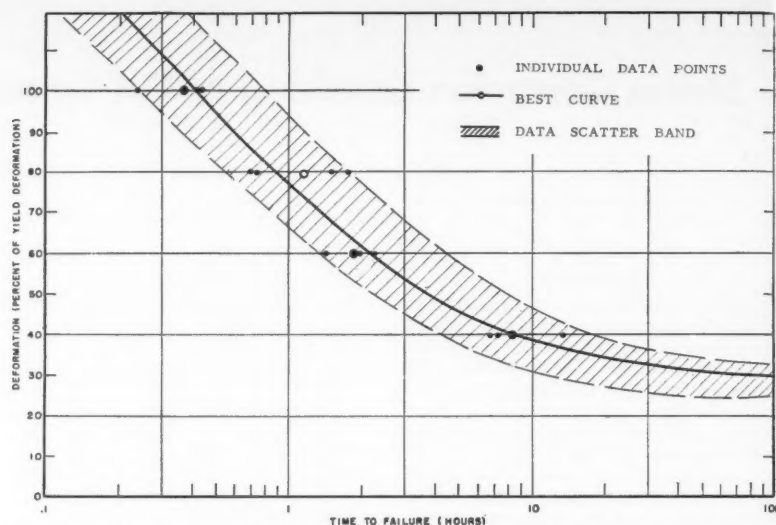


Figure 2—Time-to-failure data obtained on N-80 material, oil quenched and tempered to approximately Rockwell C 33-35 hardness, deformed to different percentages of the C-ring yield deformation and exposed to H<sub>2</sub>S saturated (3000 ppm) 5 percent NaCl.

TABLE 1—Effects of Variables on Sulfide Cracking Susceptibility of Nonalloy or Low Alloy Steels

Property	Effect on Cracking Susceptibility
Carbon Content.....	Decreases
Manganese Content.....	Increases*
Molybdenum Content.....	Increases*
Chromium Content.....	Decreases
Nickel Content.....	Increases*
Yield Strength.....	Increases*
Hardness.....	Increases*

\* An increase of the variable increases, the ease with which cracking is produced and vice versa.

that 3000 ppm of H<sub>2</sub>S was maintained in solution. Deformation versus time-to-failure data are shown in Figure 2.

Lowest level for failure was 40 percent of yield deformation. There was a scatter of times-to-failure at each stress level, but significant differences were obtained. There was only one out-of-order failure time (failure of ring at high stress in less time than one at low stress) for the 16 rings which failed. None of the eight rings loaded to 20 percent or 10 percent deformations failed. Some of the scatter which did occur was caused by hardness variations.

The notched ring test gives more reproducible results than the simple polished beam type test and made possible fairly good time-to-failure studies. It is useful as a test for below yield stress evaluations of hardness-applied stress limits.

The test's good reproducibility probably results from the localized high stress region. Surface notches in the metal such as large inclusions do not exert the scattering effect they would have on a smooth specimen. The notch concentrates stresses so that other effects are insignificant. The specimen always fails at this point where a reasonably reproducible measured stress exists.

With the polished beam specimen, there is a low stress gradient in the re-

gion of maximum stress. Small stress concentrations in the metal surface have a more exaggerated effect in displacing the failure away from the point of measured maximum stress. As a result, substantial scatter in times-to-failure for given applied stresses occurs.

Investigations using the simple polished beam specimen have given erratic results with below yield stress applications without previously cold working the specimen. Sometimes such specimens will fail but frequently they will not fail. This indicates that sulfide corrosion cracking demands at least macroscale yielding. With beam specimens pre-stressed or loaded above the yield stress, all portions of the specimen have been cold worked and are susceptible to cracking. When less than yield loads are applied to such specimens, cold work occurs only at macroscale regions where microstructural features of the specimen (inclusions, etc.) provide sufficient stress concentration to induce yielding at these places.

The notch used in this specimen does not exactly represent the different notches found in tubular goods. The notch does, however, provide a reproducible cracking susceptible region for a wide range of applied loads (40 to 100 percent of yield load). In this sense, it produces regions comparable to a wide range of notch depths and root radii. For this reason, data obtained probably does have direct engineering applicability.

### Sulfide Corrosion Cracking

#### Conditions for Occurrence

The term sulfide corrosion cracking is used to describe stress corrosion cracking of steel in sulfide environments. There has been no complete agreement among investigators whether it is a true stress corrosion cracking phenomenon or strictly a hydrogen effect.

The most comprehensive studies of this problem have been made in oil pro-

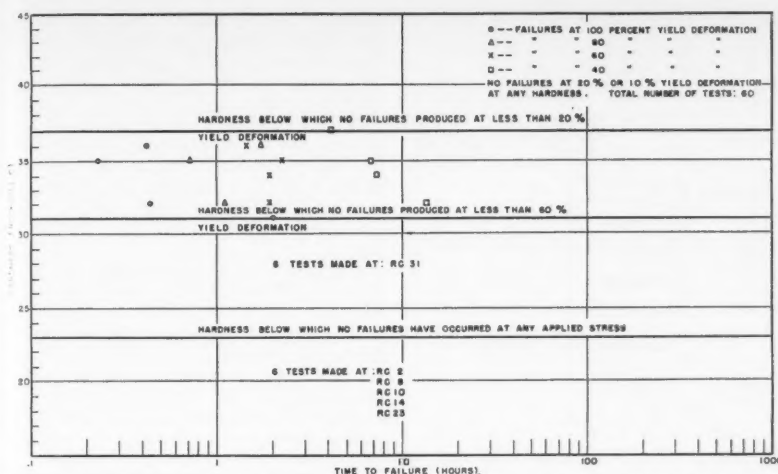


Figure 4—Hardness vs time-to-failure data obtained in tests of heat treated J-55 and N-80 in 5 percent NaCl saturated (3000 ppm) with  $H_2S$ . Insufficient data to cover entire hardness range. Data illustrates that limiting hardness level depends on applied stress.

duction.<sup>2,3,5,6-9</sup> Sulfide cracking was first encountered in 9 percent nickel steel selected for tubing in a well containing large quantities of sulfide.<sup>2</sup>

Cracking has been found to occur in any electrolyte containing  $H_2S$ . Table 2 gives a list of steels, heat treatments, hardnesses and stresses reported to result in cracking in sulfide environments.<sup>2,3,5,6</sup> Under some conditions of hardness and applied stress, these materials suffer sulfide corrosion cracking. The data is incomplete in establishing hardness-applied stress minimums for these materials.

#### Role of Hydrogen Embrittlement

Hydrogen embrittlement plays an important part in the sulfide corrosion cracking problem. One investigator used artificially induced hydrogen embrittlement by cathodic charging in 5 percent  $H_2SO_4$  with arsenic.<sup>2</sup> His tests were stress corrosion cracking studies in a sense. The data probably represented cracking susceptibility limits of various steels at extreme stress conditions. These data are given in Table 3.

Other investigations of these phenomena have shown that cracking time is related directly to the time required for hydrogen level in steel to grow to a maximum.<sup>7</sup> These studies and others have shown that, without this hydrogen pick-up, some steels cannot be caused to crack. Vollmer<sup>8</sup> and others<sup>10</sup> have shown that hydrogen charging reduces the failure strength of low and high alloy steels (see Figure 3).

On the other hand, Fraser and Treseder have shown on beam specimens covered with plastic in the high stressed region that failure occurred in lower stress regions exposed to corrosive fluids. These data seem to prove that hydrogen embrittlement is definitely necessary for failure but that the cracking is actually triggered by stress corrosion.

Other hydrogen embrittlement studies<sup>9,11</sup> showed that retained martensite in steel tends to aggravate hydrogen's embrittling effect and consequently reduces steel's cracking resistance. Tempering to eliminate retained martensite has reduced susceptibility.

Another related study<sup>12</sup> showed that the

TABLE 2—Steel Alloys, Heat Treatments, Hardness and Stresses Resulting in Sulfide Cracking\*

Steel	Heat Treatment	Minimum Hardness (RC)	Minimum Applied Stress
API J-55 <sup>a</sup> .....	Quenched and Tempered.....	30 <sup>d</sup>	80,000 <sup>b</sup>
API N-80.....	Normalized.....	24	64,000 <sup>b</sup>
	Normalized.....	21	120,000 <sup>b</sup>
	Quenched and Tempered.....	28 <sup>d</sup>	120,000 <sup>b</sup>
5% Nickel Steel.....	Normalized and Tempered.....	24	80,000 <sup>b</sup>
9% Nickel Steel.....	Normalized and Tempered Steel.....	24	60,000 <sup>b</sup>
5% Chrome Steel.....	Normalized and Tempered.....	30 <sup>d</sup>	120,000 <sup>b</sup>
0% Chrome Steel.....	Normalized and Tempered.....	25 <sup>d</sup>	120,000 <sup>b</sup>
Austenitic Stainless Steel.....	Fully Hardened.....	44 <sup>d</sup>	54,000 <sup>b</sup>
Martensitic Stainless Steel.....		25 <sup>d</sup>	100,000 <sup>b</sup>

\* Steels were stressed above the yield stress (cold worked) either before or during test. 2, 3, 5, 6.

<sup>a</sup> Not normal J-55 which is normalized to much lower hardnesses and does not normally exhibit cracking phenomenon.

<sup>b</sup> Specimens were prestressed above yield stress, then subsequently stressed to levels indicated.

<sup>c</sup> Specimens were stressed to a calculated stress which was in all cases above the yield stress of the material.

<sup>d</sup> Insufficient data available to determine these as minimum hardnesses, but they are the lowest hardnesses for which test data are reported.

corrosion product of steel in aqueous  $H_2S$  environments is  $FeS_2$ , Kansite, and that this product has some catalytic effects on the corrosion rate subsequent to its development into a scale. Kansite also may be catalyzing the  $H^+$  build-up at the metal surface and in this way causing hydrogen embrittlement.

#### More Studies Needed

Work on the sulfide corrosion cracking problem is needed in the following directions:

(a) Development of a test method which gives greater reproducibility, includes measured notch effect and permits testing without macroscale cold work of the specimen.

(b) Accumulation of more data on the hardness-applied stress minimums for cracking of different materials with notched specimens.

(c) Establishment of hardness-applied stress minimums for quenched and tempered low chemistry steels.

(d) Evaluation of corrosion control methods (inhibitors and cathodic protection) to determine their effects on hydrogen embrittlement and stress corrosion aspects of the problem.

(e) Determination of the role of  $FeS_2$  in the embrittlement phenomenon.

#### Cracking Tests Conducted

Tests were conducted to establish the hardness-applied stress limits for two API steels (N-80<sup>(1)</sup> and J-55<sup>(2)</sup>). Material for the test rings was normalized and tempered to 10 hardness levels and oil quenched and tempered to 3 hardness

(1) N-80-1 composition: 0.46 C, 0.020 P, 0.036 S, 1.00 Mn, 0.20 Mo. N-80-2 composition: 0.47 C, 0.027 P, 0.030 S, 1.50 Mn, 0.20 Mo.  
(2) J-55 composition: 0.45 C, 0.022 P, 0.025 S, 0.70 Mn, < 0.10 Mo.

TABLE 3—Minimum Hardness in Tubing Steel At Which Cracking Occurred\*

Steel	Minimum Hardness for Cracking (RC)
N-80.....	17
3 1/4% Nickel.....	20
5% Nickel.....	20
9% Nickel.....	17
9% Chrome.....	21
12% Chrome.....	19
AISI 4140.....	20

\* U-bend test specimens were exposed to artificial hydrogen embrittlement tests. Cathodic charging in 5%  $H_2SO_4$  containing 20 mg/liter of arsenic as poisoner at 2 amps/IN<sup>2</sup> for 105 min<sup>2</sup>.

TABLE 4—Sulfide Corrosion Cracking Produced in Notched Specimens Loaded Below the Yield Point

Material	Hardness (RC)	Times to Failure*
9% Chrome.....	33	Within 6 months
AISI 4145.....	30	Within 6 months
N-80 <sup>a</sup> .....	41	2 min.—41 min.
N-80.....	29	14 hours—40 hours
N-80.....	26	Less than 18 hours
N-80.....	35	2 hours—20 hours
Martensitic Stainless.....	18	Less than 24 hours
9% Chrome.....	37	Less than 12 hours

\* Times to failure vary, depending on applied stress.

<sup>a</sup> Test was such as to not permit definition of exact time to failure.

<sup>b</sup> The series of N-80 tests listed here was made on N-80 material heat treated in ways to provide different hardness levels.

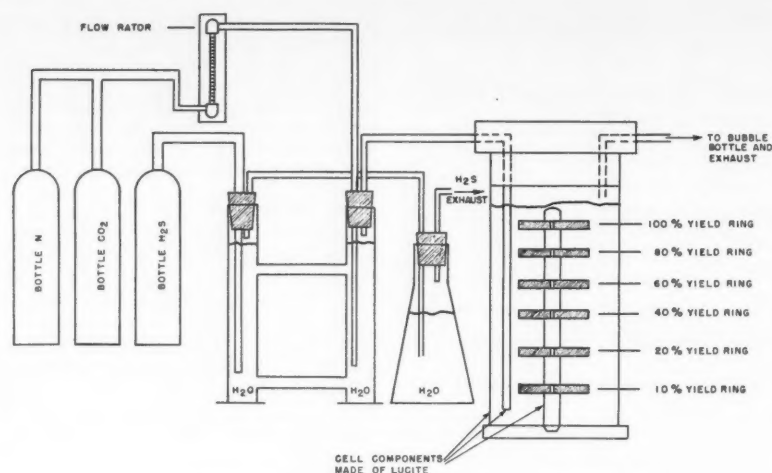
Figure 5—Laboratory set-up for conducting low H<sub>2</sub>S concentration cracking tests.

TABLE 5—Sweet Corrosion Cracking Test Results

Material	Hardness	Specimen Type	Environments	Results
9% Cr— $\frac{1}{2}$ % Mo	RC 25—RC 30	Polished Beam	Solution of 0.1% HAc + 0.1% NaCl saturated with CO <sub>2</sub>	No failures in 6 months
9% Cr— $\frac{1}{2}$ % Mo	RC 37	Polished Beam	Solution of 0.1% HAc + 0.1% NaCl saturated with CO <sub>2</sub>	No failures
9% Cr— $\frac{1}{2}$ % Mo	RC 37	Polished Beam	Solution of 0.1% HAc + 0.1% NaCl saturated with CO <sub>2</sub> + high cathodic current	No failures
9% Cr— $\frac{1}{2}$ % Mo	RC 33	Notched Ring	Vapor space above 5% NaCl solution through which was bubbled N <sub>2</sub> , CO <sub>2</sub> , and small amount of H <sub>2</sub> S (Gases in Ratio of 90% N; 9% CO <sub>2</sub> ; 1% H <sub>2</sub> S)	Failure within 6 months
N-80*	RC 35	Notched Ring	5% NaCl solution saturated with air	No failures
N-80	RC 38	Notched Ring	5% NaCl solution saturated with CO <sub>2</sub>	No failures
N-80	RC 36	Notched Ring	5% NaCl solution saturated with air and H <sub>2</sub> S	Failures within hours
9% Cr— $\frac{1}{2}$ % Mo	RC 38	Polished Beam	5% NaCl + Na <sub>2</sub> S acidified with HCl	Failure within 2 hours of acidifying
N-80	RC 35	Notched Ring	Water from Rayne Field separator	No failures
N-80	RC 35	Notched Ring	5% NaCl + N <sub>2</sub> + CO <sub>2</sub> + CS <sub>2</sub>	One failure at 500 hours
N-80	RC 35	Notched Ring	CON HCl (Not poisoned)	Failure within 2 min.
N-80	RC 35	Notched Ring	CON H <sub>2</sub> SO <sub>4</sub> (Not poisoned)	Failure within 2 min.

\* The N-80 tests listed here were made on N-80 material heat treated in ways to produce different hardness levels.

levels. Two different N-80 tubes and one J-55 tube were used.

Normalized J-55 samples ranged in hardness from RC 2 to RC 11. Quenched and tempered J-55 samples ranged from RC 14 to RC 31. N-80 samples ranged from RC 21 to RC 40. Hardnesses were obtained by using appropriate Rockwell Scale and are reported as Rockwell "C" equivalent.

Each test was continued for one month and the times to failure noted. Previous tests in saturated H<sub>2</sub>S showed that no failure can be expected after the first few days. In one test continued for one year, no failures occurred after the first day.

Tests are not complete, but results to date are given in Figure 4, which indicates definite hardness-applied stress limits.

Studies made of the problem thus far have shown that all types of steels are

susceptible to sulfide corrosion cracking. This susceptibility is a function of hardness and applied stress. Steels of different compositions and heat treatment vary in their susceptibilities. Low chemistry steels are more susceptible to the degree that they contain manganese, molybdenum and nickel; they are less susceptible to the degree that they contain chromium. All alloy steels including high chrome steels are more susceptible than low chemistry steels. All steels become more susceptible the higher their strength and hardness and have hardnesses below which they are not susceptible.

When the steels contain notches, failures occur at macroscale loads well below the yield stress of the steel. This is true of the carbon steels in Figure 4. It is also true of several alloy steels tested (see Table 4).

Tempering treatments reduce a steel's

cracking susceptibility. This probably correlates to removal of martensite in the microstructure which apparently makes the steels less susceptible to hydrogen embrittlement.

Because higher strength levels cannot be attained by normalizing and tempering low chemistry steels, the highest strength levels attainable free of cracking susceptibility probably will be with quenched and tempered low chemistry steels.

Research has given reproducible failures in J-55 and N-80 materials at many hardness levels. It clearly demonstrates that there are hardness-applied stress limits for cracking susceptibility. Work is insufficiently complete to draw further conclusions relative to the effect on susceptibility of the chemistries and heat treatments used.

### Sweet Corrosion Cracking

Twenty-one cracking failures in sweet condensate system tubing were reported in the minutes of one NACE technical committee meeting.<sup>13</sup> Some were in 9 percent chrome tubing, in 9 percent nickel and some in 5 percent nickel tubing. One committee member reported failures in N-80 at hardnesses as low as RC 22 and in AISI 4340 tubing with yield strengths ranging from 105,000 to 125,000 psi.

One company had failures in 9 percent chrome tubing in Rayne Field, La.<sup>4,18</sup> These failures occurred in material of RC 32 to 34 hardness. Tests did not result in failures in solutions containing acetic acid, mud, thread compounds, etc., saturated continuously with CO<sub>2</sub>. A polished beam specimen was used.

The most pressing need for research on the sweet corrosion cracking problem is determination of what causes cracking in the corrosive environment.

### Preliminary Tests

For almost two years after the Rayne Field failures, attempts were made to reproduce these cracking failures in a variety of sweet environments in an attempt to isolate the corroding component causing the failures. Tests involving NaCl, CO<sub>2</sub>, organic acids, muds, thread compounds and cathodic charging were tried. To date, no failures have occurred in any system not containing sulfide.

In preliminary tests in which small quantities of sulfide were added, cracking resulted. Table 5 gives a list of materials and the conditions under which they were tested.

### Field Studies

Because failures were not obtained in sulfide-free systems, a field test was begun to determine if any corrosive sulfides were present in the production from Rayne Field, La., where failures were experienced. Polished 1 by  $\frac{1}{8}$  by 8-inch copper coupons were installed in the flow streams of four wells producing from two different formations. Copper was used because of its high affinity for sulfides. If sulfide was present, it would be present in small quantities.

The coupons were exposed to the full production stream for two weeks. Scale



which formed on the coupons was analyzed by micro-chemical procedures and found to be copper sulfide. This test, qualitative in nature, showed that some sulfide was present in the production from this field.

An X-ray analysis of the corrosion scale on an AISI 4340 that had cracked showed the following constituents:  $\text{FeS}$  (Kansite),  $\text{FeCO}_3$  (Siderite) and Free Sulfur.

Both these qualitative studies gave substantial evidence that significant amounts of corrosive sulfides are present in at least some of the wells where sweet corrosion cracking has been experienced.

#### Laboratory Studies

On the hypothesis that sweet corrosion cracking occurs only where some sulfide is present, a series of tests was started to determine quantitatively the concentrations of sulfide necessary to produce failures. The tests also were to determine the time-to-failure effect of lower  $\text{H}_2\text{S}$  concentrations.

Notched ring specimens were used, and the tests were set up in the same way as for sulfide corrosion cracking. Lower concentrations of  $\text{H}_2\text{S}$  were obtained by using a diffusion tube and nitrogen- $\text{CO}_2$  carrier gas in an arrangement shown in Figure 5.

For one test, the carrier gas was flow-rated at 345 milliliters per minute nitrogen and 19 milliliter per minute  $\text{CO}_2$ .  $\text{H}_2\text{S}$  was bubbled at a slow rate. This gave a result of 50 ppm  $\text{H}_2\text{S}$  being dissolved in the test cell.

In another test, the same  $\text{N}_2$  and  $\text{CO}_2$  rates were used, but  $\text{H}_2\text{S}$  was passed over the top of the water in the diffusion tube rather than bubbling it through the water. This gave 15.2 ppm  $\text{H}_2\text{S}$  in solution in the test cell. These values were determined by iodimetric titration at the conclusion of the test run and comparison with the 3000 ppm  $\text{H}_2\text{S}$  obtained by maintaining saturation.

Test results with different concentrations of  $\text{H}_2\text{S}$  in solution are shown in Figures 6 and 7. These data clearly show that failures are produced to as low as 15 ppm  $\text{H}_2\text{S}$  in solution and that lower  $\text{H}_2\text{S}$  concentrations extend the times to failure.

Tests now in progress indicate that substantially lower  $\text{H}_2\text{S}$  concentrations will produce failures. At this lower concentration, the first failure occurred after one month (approximately 750 hours). The  $\text{H}_2\text{S}$  concentration are measured at the conclusion of the tests to get the  $\text{Fe-FeS-H}_2\text{S}$  concentration rather than the iron-free solubility  $\text{H}_2\text{S}$  concentration. For this reason, actual concentration is not yet known. The lower concentrations are being obtained by using oil in the diffusion tube on the  $\text{H}_2\text{S}$  side and by closing up the upper connection of the diffusion tube shown in Figure 5.

Sulfide is considered to be involved in these failures because of the three following factors:

First, failures have not been reproduced in laboratory prepared sulfide-free environments. Secondly, failures from two sweet condensate fields studied showed evidence that sulfide was partici-

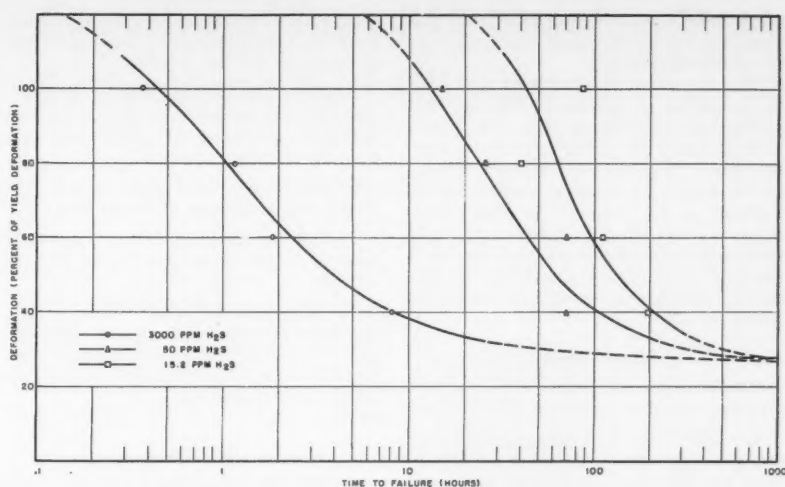


Figure 6—Time-to-failure data obtained on N-80 material, oil quenched and tempered to approximately RC 33-35 hardness in solutions containing different concentrations of dissolved  $\text{H}_2\text{S}$ .

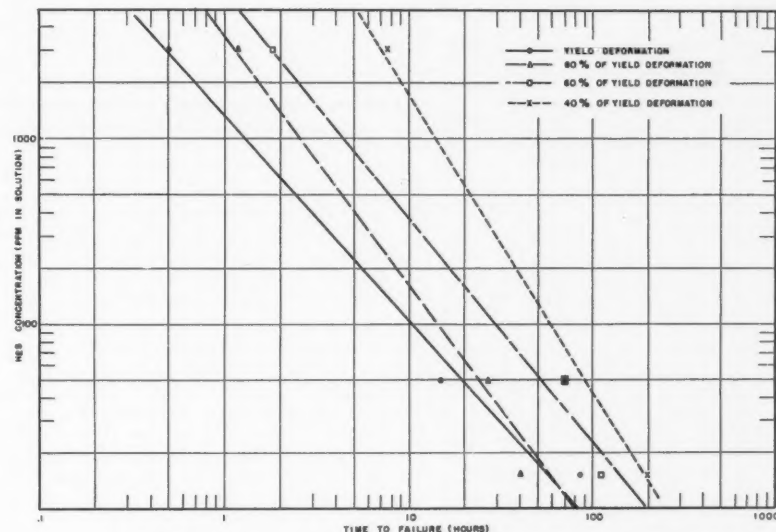


Figure 7—Time-to-failure data shown in Figure 4 plotted versus  $\text{H}_2\text{S}$  concentration.

pating in the corrosion process. Thirdly, cracking obtained at low  $\text{H}_2\text{S}$  concentration (15 ppm and less) at the extended times-to-failures at these low concentrations correlate to field failure experience.

#### Selection of Materials

Available API and non-API tubing materials probably do not have the degree of cracking resistance desired or possibly attainable with future study.

API steels (J-55 and N-80) have higher resistance than most non-API alloys.<sup>8</sup> With its normally lower hardness J-55 has the higher resistance. Because of the large property scatter exhibited by API J-55, however, it must be hardness screened to a maximum hardness of RC 22 to assure service free from cracking.

A substantial percentage of N-80 joints is above its limit of cracking suscep-

tibility.<sup>2</sup> At these hardness levels, it retains martensite in its microstructure.<sup>4,11</sup> To temper the martensite, bring the hardness down and eliminate cracking susceptibility, API N-80 must be given a special tempering treatment.<sup>6</sup> Tempering to a substandard yield strength range of 70,000 to 90,000 psi will accomplish this. Such pipe should be hardness screened to a maximum of RC 22.

Of the low alloy steels, AISI 4140 (a low chromium steel) has superior cracking susceptibility.<sup>8</sup> Normalized and tempered to 70,000 to 90,000 psi yield strength range given for N-80 will give satisfactory performance. It, too, should be hardness screened.

The higher alloys tested (9 percent nickel and 9 percent chrome steels) have high cracking susceptibilities.<sup>9</sup> The 9 percent nickel steel was first used because of its corrosion resistance in gas

condensate wells.<sup>3</sup> It has since been determined to be the most susceptible of all materials tested.<sup>3</sup>

The 9 percent chrome steel was tried by a number of operators. Although less susceptible to cracking than the 9 percent nickel steel, chrome steel is more susceptible than the low chemistry steels.<sup>3</sup> Notch sensitivity studies<sup>4</sup> show it to be superior in this respect to other materials. In some fields, it has proved highly corrosion resistant; in others it has been susceptible to pitting attack.<sup>3</sup> It is definitely cracking susceptible at hardnesses above RC 25.

#### Conclusions

1. All types of steels will crack in aqueous systems containing H<sub>2</sub>S.
2. There are hardness and applied stress minimums below which a given steel will not crack, and these minimums are inversely related.
3. Low chemistry, quenched and tempered steels are less susceptible to cracking than alloy steels for given strength levels.

4. Sweet corrosion cracking failures have not been produced in laboratory environments free of sulfide.

5. Some sweet condensate fields where cracking has occurred in tubing contain sufficient quantities of sulfide to enter into the corrosion process.

6. Cracking is produced in solutions containing 15.2 ppm H<sub>2</sub>S and less.

7. Time to cracking failure is inversely related to the concentration of H<sub>2</sub>S in solution.

8. The notched ring cracking test specimen provides more reproducible and useful hardness-applied stress failure data for below yield strength loads than polished beam specimens.

#### References

1. W. D. Robertson (editor). *Stress Corrosion Cracking and Embrittlement*. John Wiley and Sons, New York City, 1956.
2. L. W. Vollmer. Hydrogen Sulfide Corrosion cracking of Steel. *Corrosion*, 8, 326-360 (1952).
3. J. P. Fraser, G. G. Eldredge and R. S. Treseder. Laboratory and Field Methods for Quantitative Study of Sulfide Corrosion Cracking. *Corrosion*, 14, 517t (1958).
4. F. A. Prange. Mechanical Properties and Corrosion Resistance of Oil Well Tubing. *Corrosion*, 15, 49t (1959).
5. J. P. Fraser and R. S. Treseder. Resistance of Tubular Materials to Sulfide Corrosion Cracking. *Trans ASME*, 77, 817-825 (1955) August.
6. J. P. Fraser and G. G. Eldredge. Influence of Metallurgical Variables on Resistance of Steels to Sulfide Corrosion Cracking. *Corrosion*, 14, 524t (1958) Nov.
7. W. D. Robertson and Arnold E. Schuetz. Hydrogen Absorption, Embrittlement and Fracture of Steel. Report on Sponsored Research on Hydrogen Sulfide Stress Corrosion Cracking Carried on at Yale University, Supervised by NACE Technical Unit Committee T-1G. *Corrosion*, 13, 437t (1957) July.
8. L. W. Vollmer. Behavior of Steels in Hydrogen Sulfide Environments. *Corrosion*, 14, 324t (1958) July.
9. Condensate Well Corrosion. Edited by NGA Condensate Well Corrosion Committee, pp. 111-111 "Metallurgical Factors," F. A. Prange.
10. R. P. Frohberg, W. J. Barnett and A. F. Troiano. Delayed Failure and Hydrogen Embrittlement in Steel. WADC Technical Report No. 54-320 (1954) June.
11. M. F. Baldy and R. C. Bowden, Jr. Effect of Martensite on Sulfide Stress Corrosion Cracking. *Corrosion*, 11, 417t (1955) Oct.
12. F. H. Meyer, O. L. Riggs, R. L. McGlasson and J. D. Sudbury. Corrosion Products of Mild Steel in Hydrogen Sulfide Environments. *Corrosion*, 14, 109t (1958) Feb.
13. Minutes of NACE Technical Committee T-1F-2 Meeting, Sweet Corrosion Cracking Task Group of T-1F Metallurgy Committee, NACE South Central Region Conference, Oklahoma City, October 2, 1957.

Any discussion of this article not published above will appear in the December, 1959 issue

# Corrosion of Type 310 Stainless Steel By Synthetic Fuel Oil Ash\*

By HUGH L. LOGAN

## Introduction

THE PROBLEM of oil ash corrosion is not a new one. The resistances of various alloys to synthetic ash mixtures have been studied by several investigators<sup>1, 2, 3</sup> and in addition work has been done on the mechanism of oil ash corrosion.<sup>3, 4</sup>

In work done elsewhere in determining the relative susceptibility of various alloys to oil ash corrosion, the materials were placed in individual crucibles containing a synthetic oil ash and heated at a fixed temperature for a specific time. The corrosion damage was evaluated by visual or metallographic examinations, weight loss, or similar procedures.

An investigation of the corrosion of Type 310 stainless steel in fuel oil ash contaminants is in progress at the National Bureau of Standards, in cooperation with the Bureau of Ships, Department of the Navy.

The first task in the investigation was to determine the minimum temperature at which a synthetic oil ash would attack Type 310 stainless steel. The study of the mechanism of this attack on steel is a greater task and is being continued.

## Materials and Procedure

In order to obtain data for the first task at the National Bureau of Standards, the specimens in contact with synthetic ash mixtures were subjected to a temperature gradient in the range where incipient attack was expected. This was accomplished by placing the ash mixture in Type 310 steel tubes which were heated in a tube furnace adjusted so that a temperature gradient existed. The chemical analysis of the steel as determined at the NBS is given in Table 1.

The tubing, 0.80 inch OD, had a wall thickness of 0.072 inch. It was cut into 32 inch lengths, each end of each length being threaded internally so that the tube could be closed at either end or connected into a gas train so that various atmospheres could be passed through it. Prior to loading of the tubes with synthetic ash mixtures, one end was tightly packed with glass wool for a length of one to several inches before the closing plug was screwed into place. The glass wool proved effective in retaining a molten ash mixture in tubes heated in the vertical position in a tube furnace. Most of the tube was then filled with the ash mixture; a short length at the other end was also plugged with glass



About  
the  
Author

HUGH L. LOGAN has been associated with the National Bureau of Standards since 1936 where his early work dealt with corrosion and stress corrosion cracking of aluminum alloys. He received a BS in chemistry from Tarkio College and an MS in physics from the University of Colorado. He is a member of NACE, ASM, Electrochemical Society and Washington Academy of Sciences.

## Abstract

In an investigation of the corrosion of Type 310 stainless steel in synthetic fuel oil ash, the minimum temperatures at which the steel was attacked by a mixture of  $V_2O_5$  and  $Na_2SO_4$  and by mixtures of  $V_2O_5$  and  $NaVO_3$  were determined. The minimum temperatures ranged from 1075 F for a mixture of 67 percent  $V_2O_5$  and 33 percent  $NaVO_3$  to 1220 F for a mixture of 88.5 percent  $V_2O_5$  and 11.5 percent  $NaVO_3$ . An unidentified phase was produced at the interface between the steel and a vanadium compound or mixtures of compounds in the temperature range 1075 F to 1890 F. There was evidence that this phase penetrated into the steel at grain boundaries. Steel heated above 1700 F in contact with a vanadium compound or a mixture of these contained nodules of an unidentified phase at the grain boundaries. Spectrochemical analyses of the slag (fused synthetic mixture) indicated that it contained some of the components of the steel in the same proportions as they were present in the steel. 4.3.3

wool to retain the ash when the tube was heated in the horizontal position.

In order to determine the minimum temperatures at which the ash mixture attacked the steel, six chromel-alumel thermocouples, spaced one inch apart, were spot welded to the outside surface of the tube. A tube with this thermocouple arrangement is shown in Figure 1 after its removal from the furnace. In other work, four thermocouples spaced three inches apart were usually used.

The tube in position in the furnace is shown in Figure 2. There was a connection at each end of the tube for introducing air or other gases after passing them through a drier or water. These gases were then discharged into the air through the second connection at the opposite end of the tube.

Figure 1—Tube specimen after its removal from the furnace. Thermocouples were spot welded to the tube at 1 inch intervals.  $\frac{1}{4}X$ .

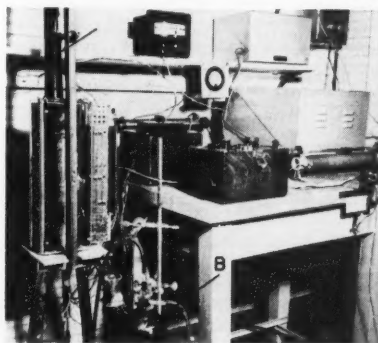


Figure 2—Tube, indicated by arrows, in place in furnace. Controls and bulb, B, containing water, through which gases were bubbled before entering the lower end of the furnace, are also shown.

TABLE 1—Analysis of Steel Used  
in Investigation

Carbon.....	0.06	Percent
Manganese.....	1.53	Percent
Phosphorus.....	0.022	Percent
Sulfur.....	.005	Percent
Silicon.....	0.19	Percent
Nickel.....	21.2	Percent
Chromium.....	24.8	Percent

\* Submitted for publication February 9, 1959. A paper presented at the Fifteenth Annual Conference, National Association of Corrosion Engineers, Chicago, Illinois, March 16-20, 1959.





Figure 3—Unidentified phase found between steel and slag in tube containing 34 percent  $V_2O_5$  + 66 percent  $NaVO_3$ ; heated to 1300 F. Etched electrolytically in 10 percent oxalic acid. 335X.

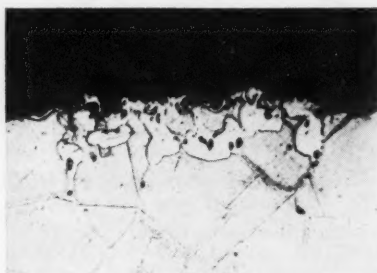


Figure 4—Massive unidentified phase penetrating into steel along grain boundaries in tube containing 67 percent  $V_2O_5$  + 33 percent  $NaVO_3$ ; heated to 1400 F. Etched electrolytically in 10 percent oxalic acid. 335X.

In the early work in this laboratory, the synthetic oil ash mixture used consisted of 85 percent  $V_2O_5$  and 15 percent  $Na_2SO_4$  (all percentages are by weight). The mixtures used in later work were made up of varying amounts of  $V_2O_5$  and  $NaVO_3$ . Attack of the steel was observed at the lowest temperature in a mixture containing 67 percent of  $V_2O_5$  and 33 percent  $NaVO_3$ ; this mixture was used in most of the work reported in this paper.

Provisions were made for placing a small diameter tube concentrically inside the regular tube but electrically insulated from it for the purpose of studying the effect of passing an electric current between the specimen tube and the smaller tube. This part of the investigation is in progress.

Most of the results reported here were obtained using mixtures of  $V_2O_5$  and  $NaVO_3$  in Type 310 stainless steel tubes into which moist air was introduced. One

experiment was made using the above mixture but introducing moist helium instead of moist air. A few experiments were run using  $V_2O_5$  or  $NaVO_3$  separately; the atmospheres introduced were wet or dry air or dry helium. The mixtures used, together with the temperature ranges and atmospheres introduced are given in Table 2.

### Results and Discussion

#### Minimum Temperatures at Which Steel was Attacked

Metallographic examinations and measurements of the wall thickness of the specimens after the removal of the oil ash mixture were used to determine the minimum temperature (maintained for 200 hours) at which the steel was attacked. These values are given in Table 2.

The minimum temperature at which the metal was definitely attacked by the

$V_2O_5$  +  $Na_2SO_4$  mixture was 1115 F. Evidences of attack at 1100 F and 1085 F were not conclusive.

Using  $NaVO_3$  +  $V_2O_5$  synthetic ash mixtures and introducing moist air the following results were obtained: (1) the tube containing 88.5 percent  $V_2O_5$  mixture showed no evidence of attack at 1150 F but slight slag attack and thinning of the specimen wall at 1220 F; (2) the specimen containing 67 percent  $V_2O_5$  mixture showed no evidence of attack at 1050 F but it had been attacked at 1075 F; (3) the specimen containing 34.5 percent  $V_2O_5$  mixture showed no evidence of attack at 1140 F but had been attacked after only a short exposure period at 1165 F.

#### Microstructure at Steel-slag Interface

If the synthetic oil ash was a mixture of  $V_2O_5$  with either  $NaVO_3$  or  $Na_2SO_4$ , a hard slag was formed that was difficult to separate from the steel. An unidentified phase, shown in Figures 3 and 4, was found in some specimens between the slag and steel; it showed a somewhat different reaction to etchants than the steel. It was a little softer than the steel; Knoop hardness numbers for this phase and the steel, determined on a specimen heated to 1390 F, were 155 and 179 respectively. The unidentified phase formed a more nearly continuous layer between the slag and steel in specimens heated in the 34.5 percent  $V_2O_5$ —65.5 percent  $NaVO_3$  mixture than in any of the other mixtures studied. Figure 3 shows this layer in contact with steel heated for three hours at 1165 F and for 197 hours at 1115 F. The unidentified phase in specimens heated in the 67 percent  $V_2O_5$ —33 percent  $NaVO_3$  mixture was gen-

TABLE 2—Synthetic Oil Ash Mixtures, Atmospheres, and Temperature Ranges to Which Type 310 Stainless Steel Tubing Was Exposed

Atmosphere	V <sub>2</sub> O <sub>5</sub>	NaVO <sub>3</sub>	85% V <sub>2</sub> O <sub>5</sub> + Na <sub>2</sub> SO <sub>4</sub>		88.5% V <sub>2</sub> O <sub>5</sub> + NaVO <sub>3</sub>		67% V <sub>2</sub> O <sub>5</sub> + NaVO <sub>3</sub>		34.5% V <sub>2</sub> O <sub>5</sub> + NaVO <sub>3</sub>		Compounds Identified in the Slag*
	Temp, Degrees F	Temp, Degrees F	Temperature, Degrees F		Temperature, Degrees F		Temperature, Degrees F		Temperature, Degrees F		
	Range Studied	Range Studied	Range Studied	Minimum Tem- perature of Attack	Range Studied	Minimum Tem- perature of Attack	Range Studied	Minimum Tem- perature of Attack	Range Studied	Minimum Tem- perature of Attack	
Dry Air . . . . .	1195-1800	.....	.....	.....	1305-1495	.....	.....	.....	.....	.....	V <sub>2</sub> O <sub>5</sub> NiO-V <sub>2</sub> O <sub>5</sub> ; FeVO <sub>4</sub> ;
Wet Air . . . . .	1805-1890	.....	.....	.....	.....	.....	.....	.....	.....	.....	V <sub>2</sub> O <sub>5</sub> ; NiO-V <sub>2</sub> O <sub>5</sub> ; CrVO <sub>4</sub> ; 2NiO-V <sub>2</sub> O <sub>5</sub> ; V <sub>2</sub> O <sub>5</sub>
Wet Air . . . . .	.....	.....	.....	.....	920-1475	1220	.....	.....	.....	.....	No X-Ray Data
Wet Air . . . . .	.....	.....	.....	.....	.....	.....	990-1780	1075	.....	.....	NaVO <sub>3</sub> ; 2NiO-V <sub>2</sub> O <sub>5</sub>
Wet Air . . . . .	.....	.....	.....	.....	.....	.....	.....	.....	940-1350	1165	No X-Ray Data
Wet Air . . . . .	.....	2090	.....	.....	.....	.....	.....	.....	.....	.....	Na VO <sub>3</sub> ; NaVO <sub>3</sub> ·H <sub>2</sub> O
Wet Air . . . . .	.....	.....	920-1550	1115	.....	.....	.....	.....	.....	.....	Na <sub>2</sub> O·V <sub>2</sub> O <sub>4</sub> ·5V <sub>2</sub> O <sub>5</sub> **
Dry Helium...	1340-1870	.....	.....	.....	.....	.....	.....	.....	.....	.....	2NiO-V <sub>2</sub> O <sub>5</sub> ; V <sub>2</sub> O <sub>5</sub> ; (V <sub>2</sub> O <sub>5</sub> ; Fe <sub>2</sub> O <sub>3</sub> ·2V <sub>2</sub> O <sub>5</sub> ; Cr <sub>2</sub> O <sub>3</sub> ·V <sub>2</sub> O <sub>5</sub> ) ?
Dry Helium...	.....	1490-1805	.....	.....	.....	.....	.....	.....	.....	.....	No X-Ray Data
Wet Helium...	1850-1895	.....	.....	.....	.....	.....	.....	.....	.....	.....	2NiO-V <sub>2</sub> O <sub>5</sub> ; FeVO <sub>4</sub> ; Fe <sub>2</sub> O <sub>3</sub>
Stagnant Air..	.....	.....	.....	.....	.....	.....	1270-2030	.....	.....	.....	V <sub>2</sub> O <sub>5</sub> ; NaVO <sub>3</sub> ·H <sub>2</sub> O; NiO·H <sub>2</sub> O; Cr <sub>2</sub> O <sub>3</sub> ; Na <sub>2</sub> O·V <sub>2</sub> O <sub>4</sub> ·5V <sub>2</sub> O <sub>5</sub> 5Na <sub>2</sub> O·V <sub>2</sub> O <sub>4</sub> ·11V <sub>2</sub> O <sub>5</sub> ; (FeVO <sub>4</sub> ; FeV) ?
Stagnant Air..	.....	.....	.....	.....	.....	.....	.....	.....	1130-1320	.....	V <sub>2</sub> O <sub>5</sub> ; NaVO <sub>3</sub> ·H <sub>2</sub> O

\* By X-Ray Diffraction Techniques.

\*\* Ohio State University Research Foundation Report, 692-6, by Thomas S. Shevlin

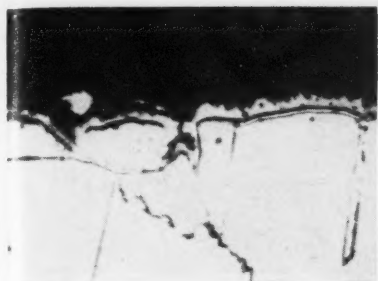


Figure 5—Unidentified phase surrounding a crystal of steel in tube containing 100 percent  $V_2O_5$  with moist air atmosphere heated to 1890 F. Etched electrolytically in 10 percent oxalic acid. 500X.

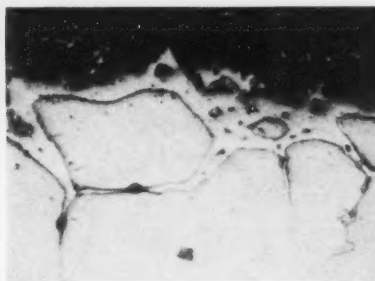


Figure 6—Unidentified phase surrounding several crystals and penetrating along grain boundaries in Type 302 stainless steel. Etched electrolytically in 30 ml  $HNO_3$  + 20 ml acetic acid. 335X.

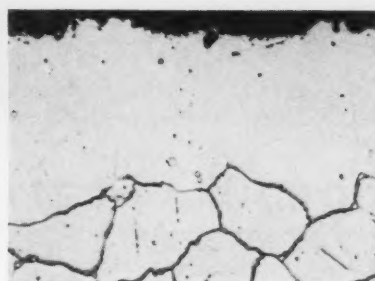


Figure 7—Nodules, most probably of a second unidentified phase, at grain boundaries. Etchant 30 ml  $HNO_3$  + 20 ml acetic acid. 335X.

ally discontinuous with the penetration occurring at grain boundaries. Figure 4 shows typical penetration of this phase into the steel.

The unidentified phase was found in tubes containing  $NaVO_3$  that had been heated to about 1400 F. In tubes containing the mixture of 67 percent  $V_2O_5$  + 33 percent  $NaVO_3$  the phase was found after heating at temperatures as high as 1650 F. It was also found after heating at a temperature as high as 1890 F in a tube containing  $V_2O_5$ . Figure 5 shows this phase almost completely surrounding a grain of the steel in this tube. This phase was definitely dependent on the presence of a vanadium compound or on a mixture containing two vanadium compounds. No evidence of such a phase was found in tubes containing no vanadium compounds heated to temperatures of 1950 F in contact with wet helium and 1750 F in contact with wet air.

In one instance a mixture of  $V_2O_5$  (67 percent)— $NaVO_3$  was inadvertently spilled onto the external furnace tube of Type 302 stainless steel. This tube was subsequently heated to 1780 F and was found to be much more severely attacked, Figure 6, than the Type 310 steel heated to the same temperature. The photomicrographs, Figures 5 and 6, suggest that the unidentified phase penetrating along the grain boundaries may engulf individual crystals of the steel.

In the interior of the steels heated to 1700 F or higher, in contact with either  $NaVO_3$  or  $V_2O_5$  or a mixture of the two, a constituent was found at the grain boundaries as is shown in Figures 7 and 8. This constituent was not found in specimens heated to the same temperature but not in contact with any vanadium compound.

Etching of the steels that had been heated for six hours or longer at temperatures above 1600 F indicated that materials in addition to carbides were precipitated at the grain boundaries. This condition, existing whether or not any vanadium compound had been present, is shown in Figure 9. The same specimen, etched in NaCN to reveal the presence of carbides, is shown in Figure 10. A very wide grain boundary structure developed by etching the steel in 30 ml of  $HNO_3$  plus 20 ml of acetic acid is shown in Figure 11. It was noted

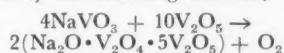
that the cyanide etchant did not attack the twin boundaries at all and that the other etchants attacked them much less severely than the grain boundaries.

In only one instance was a definite intercrystalline phase found in the specimen in the unetched condition. Figure 12 shows a section of tubing that was completely immersed in  $V_2O_5$  at 1855 F with moist air flowing through the container tube. A platinum wire marker was spot welded to the specimen prior to heating. On examination after six hours at temperature the platinum marker was separated from the steel by a layer of slag approximately 0.05 inch thick. The container tube (Type 310 stainless steel) was deeply grooved at the contact of the  $V_2O_5$  slag with the atmosphere.

#### Changes in Gas Content in a Closed System.

Several of the tube specimens were made parts of a closed system that included gas measuring and gas collecting tubes. Thus, it was possible to determine qualitatively the change in the volume and semi-quantitatively the changes in composition of the atmospheres in the closed systems.

On the first heating of the  $V_2O_5$  +  $NaVO_3$  mixture, more gas was evolved than was expected from expansion alone. Analysis of the gas by mass spectrographic methods indicated that it contained more oxygen than is found in air. Heating a mixture of  $V_2O_5$  alone in the tube resulted in a decrease in volume of the gas, as has been reported by Monkman and Grant,<sup>5</sup> and a decrease in the oxygen content. Similar results were obtained using  $NaVO_3$  alone. These results indicate that the increase in oxygen content of the gas must be due to the interaction of the  $V_2O_5$  and  $NaVO_3$ . Oxygen also was obtained by Shevlin<sup>6</sup> on heating a mixture of these compounds. He suggested that it was produced by the following reaction;



and reported that he had obtained the X-ray diffraction pattern corresponding to the complex product. Diffraction patterns of this compound and also of  $5Na_2O \cdot V_2O_4 \cdot 11V_2O_5$  were obtained for the slags formed in these experiments.

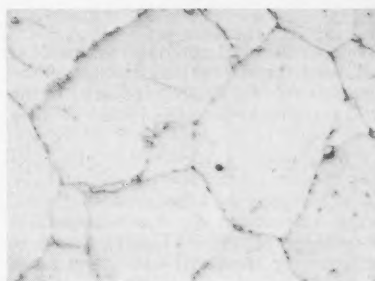


Figure 8—Nodules at grain boundaries in interior of steel. Etched electrolytically in 10 percent oxalic acid. 500X.

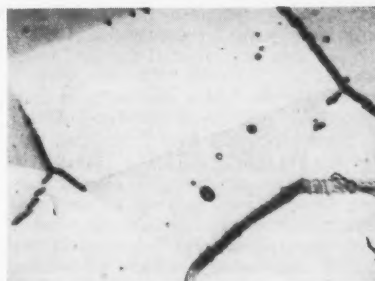
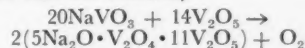


Figure 9—Unusual structures found at grain boundaries of steels heated to 1890 F. Etched electrolytically in 10 percent oxalic acid. 335X.

The presence of the latter product suggests that the reaction,



also may occur.

#### Slag Produced on Heating Vanadium Compounds in Steel Tubes.

Heating of either the  $NaVO_3$  or the  $Na_2SO_4$  with  $V_2O_5$  produced a hard, dark, granular slag that was difficult to remove from the steel. In some instances needle-like crystals were found above the surface of the slag that had been molten. The various compounds identified in the slag by X-ray diffraction methods are given in Table 2. Efforts to separate the slag completely into its components have not been successful. Some slag components were soluble in water; others were soluble in a hot NaOH solution, so that only partial separations have been made. However, there were usually some unidentified lines in the diffraction patterns.



Figure 10—Structure of same specimen as Figure 9 but etched electrolytically in 10 percent NaCN, showing that complex structure was not due to carbides. 500X.

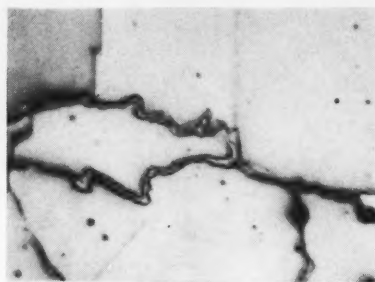


Figure 11—Grain boundary structure of specimen heated to 2090 F in  $\text{NaVO}_3$  and moist air. Etched electrolytically in 30 ml  $\text{HNO}_3$  + 20 ml acetic acid. 500X.

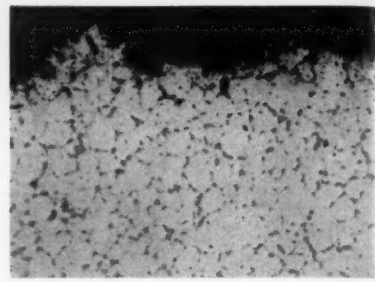


Figure 12—Structure of piece of tubing completely immersed in  $\text{V}_2\text{O}_5$  at 1870 F with a moist air atmosphere. Note the intercrystalline penetration or agglomeration of an unidentified phase at the grain boundaries. Unetched. 335X.

Spectrochemical analyses of the slag indicated that it contained some of the components (Fe, Cr, Ni, and Mn) of the steel in the same proportions as they were found in the steel itself. There was no microscopic evidence that the steel was present in the slag in the metallic form. It is suggested that crystals of steel, being surrounded by the unidentified phase as is shown in Figures 5 and 6, subsequently combined with components of the slag. Data in Table 2 indicate that components of the steel were present in the slag in the form of such compounds as  $\text{NiO} \cdot \text{V}_2\text{O}_5$ ,  $2\text{NiO} \cdot \text{V}_2\text{O}_5$ ,  $\text{CrVO}_4$ ,  $\text{Fe}_2\text{O}_3 \cdot 2\text{V}_2\text{O}_5$  and possibly  $\text{FeVO}_4$ . Evidences of vanadium-nickel compounds were found more frequently than for vanadium with any other of the steel components.

The slag conducted electricity in both the liquid and the solid states. When platinum electrodes were introduced into the two ends of a solid slag cylinder in a temperature gradient, an electric current flowed from the hot to the cold junction when the circuit was closed. The electric potential behavior of the molten slag, using platinum electrodes, was very erratic.

#### Summary

1. The minimum temperatures at which four synthetic oil ash-mixtures attacked Type 310 stainless steel was studied as was the mechanism of this attack.

2. A mixture of 67 percent  $\text{V}_2\text{O}_5$  +

33 percent  $\text{NaVO}_3$  attacked the steel at 1075 F. Mixtures of  $\text{V}_2\text{O}_5$  +  $\text{NaVO}_3$  containing 34.5 percent and 88.5 percent of  $\text{V}_2\text{O}_5$  attacked the steel at 1165 F and 1220 F, respectively. A mixture of 85 percent  $\text{V}_2\text{O}_5$  + 15 percent  $\text{Na}_2\text{SO}_4$  attacked the steel at 1115 F.

3. An unidentified phase structure developed at the steel/slag interface and penetrated into some grain boundaries at this interface on heating  $\text{V}_2\text{O}_5$ ,  $\text{NaVO}_3$ ,  $\text{V}_2\text{O}_5$  +  $\text{NaVO}_3$ , or  $\text{V}_2\text{O}_5$  +  $\text{Na}_2\text{SO}_4$  in a steel tube at temperatures in the range 1100 F to 1850 F. The maximum temperature at which this phase occurred at the interface varied with the vanadium content of the compound or mixture ranging from 1450 F for  $\text{NaVO}_3$  alone to 1850 F for  $\text{V}_2\text{O}_5$ .

4. At high temperatures the unidentified phase penetrated into the steel along the grain boundaries and in some instances completely surrounded grains of steel.

5. An unidentified phase was found in the steel heated above 1700 F in contact with a vanadium compound.

6. The slag contained some components of the steel in approximately the same proportions as they were found in the steel. X-ray diffraction patterns of the slag indicated that it contained  $\text{NiO} \cdot \text{V}_2\text{O}_5$ ,  $2\text{NiO} \cdot \text{V}_2\text{O}_5$ ,  $\text{CrVO}_4$ ,  $\text{Fe}_2\text{O}_3 \cdot 2\text{V}_2\text{O}_5$  and possibly  $\text{FeVO}_4$ .

7. The slag obtained by heating a mixture of 33 percent  $\text{NaVO}_3$  + 67 percent  $\text{V}_2\text{O}_5$  conducted electricity in both the liquid and solid state. When plati-

num electrodes were introduced into the two ends of a solid slag cylinder in a temperature gradient, an electric current flowed from the hot to the cold junction when the circuit was closed.

#### Acknowledgment

This investigation was supported by the Bureau of Ships, Department of the Navy. The author expresses his appreciation to the Bureau of Ships for permission to publish this paper. The conclusions drawn from these data are his own and not necessarily those of the Bureau of Ships.

William Ambs, Joan P. Calvert, June Y. Chung, James G. Early, Jr., Joseph E. Himes, and Raymond S. Smethurst, Jr., assisted in this investigation.

#### References

1. B. O. Buckland, G. M. Gardiner, and D. G. Sanders. Residual Fuel-oil Ash Corrosion. Paper No. 52-A161, ASME Ann. Meeting, 1952.
2. C. T. Evans. Oil-ash Corrosion of Materials at Elevated Temperatures. Symposium on Corrosion of Materials at Elevated Temperatures, Special Tech. Pub. 108, 59 ASTM (1950).
3. A. deS. Brasunas and N. J. Grant. Accelerated Oxidation of Metals at High Temperatures. *Trans. ASM*, 44, 1117 (1952).
4. G. W. Cunningham and A. deS. Brasunas. The Effects of Contamination by Vanadium and Sodium Compounds on the Air-corrosion of Stainless Steel. *Corrosion*, 12, 389t (1956).
5. F. C. Monkman and N. J. Grant. An Investigation of Accelerated Oxidation of Heat-resistant Metals due to Vanadium. *Corrosion*, 9, 460 (1953).
6. T. S. Shevlin. Effect of Specific Corrodents on Type 310 Stainless Steel. Final Report, Ohio State University Research Foundation, RF Project 692-6, June, 1957.

Any discussion of this article not published above will appear in the December, 1959 issue





## TECHNICAL COMMITTEE ACTIVITIES

# Eight Committees Give Reports at Chicago

### T-5B

Three guest speakers were included at the March meeting of Unit Committee T-5B, High Temperature Corrosion, held in Chicago.

A. B. Michaels, director of Research of Fansteel Metallurgical Corp., reviewed current developments of oxidation resistant columbium, tungsten and tantalum alloys. S. W. Bradstreet, Mineral and Ceramic Division of Armour Research Foundation, discussed refractory high temperature coatings. J. I. Bonin, Chicago Midway Laboratories, described the mechanism of ablative cooling and showed films of materials being exposed in the laboratory to thermal environments simulating re-entry missile nose cones.

The meeting also included a discussion of residual fuel oil ash corrosion problems. Recent efforts to solve boron high energy fuel combustion product corrosion problems were reviewed.

### T-2A

Status of task groups was discussed at the Chicago meeting of Unit Committee T-2A, Galvanic Anodes. Task Group T-2A-1, assigned to correlate data from galvanic anode operating installations, was disbanded because insufficient data was received.

Task Group T-2A-2, Development of Standard Accelerated Galvanic Anode Test Procedures, was reactivated. Present members are to be contacted.

A committee was appointed to investigate the feasibility of compiling and correlating galvanic anode information, data and developments and to make recommendations on formulation and presentation of practical reports on galvanic anodes by T-2A. Committee members appointed are E. A. Anderson, chairman, T. J. Lennox, R. L. Horst, W. P. Noser and H. W. Wahlquist.

### T-6F

Three discussion topics were presented at the Chicago meeting of Unit Committee T-6F, Protective Interior Linings, Applications and Methods.

Topics were chemical plant patching with polyester, epoxy and glass cloth by W. A. Szymanski, Swedish pictorial standards on surface preparation by K. Tator and pitfalls to avoid in immersion panel testing by K. Tator.

Reports from three task groups on curing, inspection and ethics of application contractors were given at the meeting.

### T-4E

A preliminary report on preparation of pipe specimens exposed to different water conditions and a discussion on cathodic protection for hot water tanks

were included at the Chicago meeting of Unit Committee T-4E, Corrosion by Domestic Waters.

A display of 87 pipe specimens exposed to water conditions in the United States and Canada was shown by T. E. Larson. He distributed to members a data sheet listing the water source, treatment, analyses, saturation indices, approximate flow rates and water pressure applied to the specimens.

H. C. Fischer was appointed chairman of a sub-committee on hot water tank corrosion to determine desired cathodic protection current for protection of hot water tanks in different U. S. cities.

### T-2B

Two new task groups were established at the Chicago meeting of Unit Committee T-2B, Anodes for Impressed Current. They are T-2B-6, Deep Anodes, and T-2B-7, Use of Lead and Lead Alloys as Anodes. T-2B-6 chairman is A. W. Peabody, Ebasco Services, Inc., New York City; T-2B-7 chairman is E. J. Mullarkey, Lead Industries Association, New York City.

Task Group T-2B-5, Use of Platinum, Palladium, etc., for Anodes, was disbanded because Unit Committee T-3G is handling similar work.

Reports were given by the various task group chairmen on the status of their groups.

### T-6R

Film thickness for protection of hot rolled steel was discussed by G. G. Schurr at the Chicago meeting of Unit Committee T-6R, Protective Coatings Research. The report was an activity of the Corrosion Sub-committee of the Research Advisory Committee of the Federation of Paint and Varnish Production Clubs. The project was to determine if all organic coatings require the same minimum film thickness for economical protection of hot rolled steel against atmospheric corrosion.

The committee heard reports on various projects of interest which the American Welding Society and Steel Structures Painting Council are conducting.

The committee will prepare a questionnaire to help in determining definitions of various terms pertinent to lining and coating applications which will be useful to other unit committees.

### Cathcart With Tank Lining

W. P. Cathcart, recently elected chairman of Technical Committee T-6F, Protective Interior Linings, Application and Methods, is affiliated with Tank Lining Corp., Pittsburgh, Pa. Caption under his photograph published in the June issue of CORROSION incorrectly listed his company affiliation as Oak Ridge National Laboratories.

### T-6A

A paper on Testing of Chemical Resistant Coatings for Chemical Plant Atmospheres was presented by F. Parker Helms at the March meeting of Unit Committee T-6A, Organic Coatings and Linings for Resistance to Chemical Corrosion, held at Chicago.

He briefly described the methods for evaluation and pointed out the need for correlation of test procedures and field performance. He reported that the most reliable indication of performance was application of coatings to relatively large test areas such as drums. These tests of porosity must be followed by larger field application tests.

Reports from T-6A task groups also were given at the meeting.

### T-3A

Salesmen should be more factual in presenting their products and should direct their sales at the operator level, according to a discussion held at the Chicago meeting of Unit Committee T-3A.

Sales information should give facts and figures relating to a specific operation. An example was given at the meeting of a salesman who sold an inhibitor for a hydrocarbon stream at 600 to 700 F. A monomolecular film could not be maintained at these temperatures for the given product.

T-3A members emphasized that such incidents tend to reduce the operator's confidence in other products.

## 3rd Committee Joins Southeast Region's Coordinating Group

The Tidewater Corrosion Control Committee, covering the Norfolk, Portsmouth and Newport News area, has joined the T-7C Southeast Region Corrosion Coordinating Committee. It is the third to join T-7C.

Organized in 1952, the Tidewater Committee has members representing utility companies, municipalities and naval activities in its area and from Atlanta and Washington, D.C.

The committee meets quarterly in a joint meeting with the NACE Tidewater Section.

Committee chairman is E. W. Seay, Jr., plant engineer for Chesapeake and Potomac Telephone Company of Virginia. He is also chairman of T-7C. Secretary is S. P. Edwards, underground distribution superintendent with Virginia Electric and Power Co., Norfolk, Va.

Nineteen technical committee meetings are scheduled for the South Central Region Conference, October 12-15, in Denver, Colorado.



## COREXIT cuts lifting costs . . . saves up to \$1,000 a year per well

COREXIT saves you money. It prolongs the life of your sub-surface equipment, reduces the number of well-pulling jobs and prevents loss in production. Savings up to \$1,000 a year per well are not unusual.

The initial COREXIT treatment cleans up your sub-surface equipment, displacing corrosive brine and loose scale from metal surfaces. Then it builds up a tenacious and lasting protective film on these metal surfaces to prevent further corrosion and hydrogen embrittlement. Periodic COREXIT batch treatments with a few hours circulation of the production will give continued protection.

COREXIT is an organic, adsorptive-type corrosion inhibitor. It is available in many different formulas to meet the needs of every producer. It is non-toxic and easy to handle. It has no objectionable odor.

Save your money — use COREXIT!

HUMBLE OIL & REFINING COMPANY

**HUMBLE**



COREXIT is readily available from Humble wholesale plants throughout Texas and New Mexico. Call the one nearest you for quick on-the-lease or plant delivery, or phone or write:

Humble Oil &  
Refining Company  
Consumer Sales  
P. O. Box 2180  
Houston 1, Texas

COREXIT is also available through these companies:

in Oklahoma and Kansas—

Pet-Chem, Inc.  
Mayo Building  
Tulsa, Oklahoma

in Illinois, Indiana and Kentucky—

T. E. Bennett  
Chemical Company  
P. O. Box 245  
Salem, Illinois

in Western Canada—

Rice Engineering &  
Operating Ltd.  
10509-81 Avenue  
Edmonton, Alberta



# NACE NEWS

## Wide Scope of Topics Features Fall Meetings

Topics to Be Discussed at 1959 NACE Region Conferences

Region, Place	Biological	Cathodic Protection			Chemical Processing	Coatings	High Temperature	Inhibitors	Oil, Gas Production	Pipeline	Plastic	Pulp, Paper	Refineries	Stress Corrosion	Theory	Utilities	Water
		Interference	Marine	Miscel.													
Western Bakersfield			X		X	X			X	X			X			X	
Southeast Jacksonville	X			X		X					X	X	X				
Northeast Baltimore	X	X	X	X		X	X	X						X	X		X
South Central Denver							X		X	X			X			X	
North Central Cleveland				X		X	X	X			X						

## Several Industries' Corrosion Problems To Be Discussed

Five NACE region conferences scheduled for September and October will discuss corrosion control problems ranging in scope from biological aspects and theory of corrosion to water problems.

A concentration of information on coatings, cathodic protection and refineries will be presented in technical papers and discussions at the five conferences. Corrosion problems in the chemical processing, oil and gas production, pulp and paper and utilities industries also will be included in the technical programs.

The table at left indicates the topics to be discussed at each of the region conferences.

The first conference will be the Western Region, Sept. 29-Oct. 1, to be held at the Bakersfield Inn, Bakersfield, Cal. Abstracts of technical papers to be presented at this conference appear in this issue of CORROSION.

The 1959 Southeast Region Conference will be held at the Robert Meyer Hotel, Jacksonville, Fla., Oct. 5-8. Abstracts of papers for this program also are published in this month's CORROSION.

A complete schedule of events, abstracts of papers and photos and biographies of authors for the 1959 Northeast Region Conference appear in this issue. This conference will meet Oct. 5-8 at the Lord Baltimore Hotel in Baltimore, Md.

Advance information is given in this month's CORROSION on the other two conferences. They are the South Central Region, which will meet Oct. 12-15 at the Cosmopolitan Hotel in Denver, Colo., and the North Central Region, which will meet Oct. 20-22 at the Statler-Hilton Hotel in Cleveland, Ohio.

Final programs for these two conferences are scheduled for publication in the September issue of CORROSION.

4th Annual Corrosion Control Short Course sponsored by the Miami Section will be held November 16-20 at the Key Biscayne Hotel, Miami, Florida.

7464 copies of NACE Technical Committee Reports published in CORROSION were sold in 1958.

## March '59 Corrosion Issues Needed for Library Uses

Copies of the March, 1959 issue of CORROSION are needed to fill Volume 15 for library subscribers. Any CORROSION reader who no longer needs to keep the March issue for reference is asked to send it to Central Office NACE, 1061 M & M Bldg., Houston 2, Texas, attention N. E. Hamner. The issues received will be sent to library subscribers.

## North Central Region News

### Cleveland Conference To Have 30 Papers

Thirty papers are to be presented in four symposia at the 1959 North Central Region Conference, October 20-22 at the Statler-Hilton Hotel, Cleveland, Ohio.

Eight NACE Technical Committee meetings also are scheduled during the conference: T-2L (Wax Type Pipe Coatings and Component Wrappers), T-3F-2 (Inhibitors), T-5C-2 (Corrosion by Cooling Waters—North Central Region), T-5D (Plastic Materials of Construction), T-6H (Glass Linings and Vitreous Enamels), T-7 (Corrosion Coordinating Committee), T-7B (North Central Region Corrosion Coordinating Committee) and T-6F (Protective Interior Linings, Applications and Methods).

A special plant visit is also planned as part of the program.

#### Four Technical Symposia

The four symposia and the chairmen of each are given below:

Protective Coatings: Paul Gegner, Columbia Southern Chemical Co., and S. W. McIlrath, Diamond Alkali Co.

Chemical Treatment: Fred B. Hamel, Standard Oil Company of Ohio.

Materials of Design: (Metals) Anton De S. Brasunas, American Society of Metals; (Plastics) J. F. Malne, B. F. Goodrich Co., and R. B. King, Heil Process Equipment Co.

Cathodic Protection: B. Husock, Harco Corp., and J. J. Pokorny, Cleveland Electric Illuminating Co.

#### Scope of Technical Information

Designed to include technical information of interest to persons involved in corrosion control work in the North Central area, the program's scope is indicated by these titles: American Experience With Inhibitors in Low Temperature Service, Four Years' Experience in Treating a Cooling Water System for Corrosion Control, Protective Coating Testing by the User, Good Design Promotes Good Service, Plastic Materials of Construction for Corrosive Environments—Their Testing and Evaluation, Cathodic Protection Program for Industrial Water Storage Tanks, Specialty Coatings for Corrosion Protection and Selection and Design of Structural Plastic Equipment.

#### Complete Program to Be Published

A complete program of the conference is scheduled for publication in the September issue of CORROSION. This will include a listing of the technical paper abstracts, schedule of events, registration information and biographies and photographs of the authors.

### NEWS DEADLINE FOR CORROSION

News intended for publication in CORROSION should be in Houston not later than the 10th of the month preceding month of publication. When events occur at or near this date, it sometimes is possible to hold space for news stories, provided advance notice is given. An estimate of the amount of space required should be included in the advance notice.



## South Central Region News

### Denver Conference Final Plans Are Set

Final plans are being completed for the 1959 South Central Region Conference to be held October 12-16 in Denver, Colorado. Headquarters for the conference will be the Cosmopolitan Hotel; room reservations are being made at the Brown Palace Hotel also.

#### Technical Program

Six symposia and a series of educational lectures are scheduled to present about 30 technical papers on a wide variety of corrosion control subjects.

The six symposia and the chairman and co-chairman of each are listed below:

**Pipeline Corrosion:** Frank D. Burns, General Asphalts, Inc., Wynnewood, Okla., and M. J. Olive, Arkansas Fuel Oil Corp., Shreveport, La.

**Refining and Chemical Process Industries:** E. L. Haile, Monsanto Chemical Co., Texas City, Texas, and L. M. Roger, Union Carbide Chemicals Co., Texas City, Texas.

**Oil and Gas Production:** W. C. Koger, Cities Service Oil Co., Bartlesville, Okla., and J. A. Caldwell, Humble Oil and Refining Co., Houston, Texas.

**Utilities and Communication Industries:** Glenn W. Beasley, Dallas Power and Light Co., Dallas, Texas, and T. J. Maitland, American Telephone and Telegraph Co., New York, N. Y.

**High Temperature Corrosion:** J. J. Moran, International Nickel Co., Inc., New York, N. Y., and J. H. Devan, Oak Ridge National Laboratory, Oak Ridge, Tenn.

**Fresh Water Corrosion:** J. M. Brooke, Phillips Petroleum Co., Sweeny, Texas, and Roy V. Comeaux, Humble Oil and Refining Co., Baytown, Texas.

#### Other Conference Activities

Other conference activities scheduled are tours of the Bureau of Reclamation Laboratories and the Ohio Oil Company Laboratory, fellowship hour, dinner-dance and business luncheon.

Seventeen technical committee meetings are scheduled during the conference. These are T-1, T-1B, T-1D, T-1E, T-1F, T-1H, T-1H-3, T-2D, T-2K-1, T-3K-2, T-6A, T-6D, T-8, T-8A, T-6E, T-6B, and T-2.

The Educational Committee for the South Central Region has scheduled a luncheon meeting also.

#### Complete Program to Be Published

Complete program of the conference is scheduled for publication in the September issue of CORROSION. This will include a timetable of all events, abstracts of technical papers to be presented, photographs and biographical sketches of authors, social events and the ladies program.

**North Texas Section** was invited to attend the local section meeting of the Society of Plastics Engineers. Engineering applications, problems and limita-

tions of plastic pipe was the program subject.

A joint meeting of the North Texas Sections of NACE and SPE is scheduled for September.

**Alamo Section** had the first of three educational programs on corrosion processes and control at its June 16 meeting. Gene Kneuper of the San Antonio Public Service Board presented a film by Alnico Corporation.

**Greater Baton Rouge Area Section** sponsored a 9-week maintenance painter

course to present new developments and equipment in the painting and coatings fields. Classes were held each Monday night beginning February 9.

Speakers who participated in the course included R. W. Swandby, Wyandotte Chemical Corp., E. W. Oaks, Clementina Ltd., John W. Nee, Briner Paint Co., Joe Rench, Napco Corp., Norman T. Schideler, Pittsburg Coke and Chemical Co., John Rogers, Amercoat Corp., V. B. Volkening, Dow Chemical, Frank Faust, DeVilbiss, Lee McIlhane, DeVilbiss, Jack Anderson and Jim Seifert, Graco, Arch Evans, Spec-Flo and Woody Gilpin, K-Way Equipment.

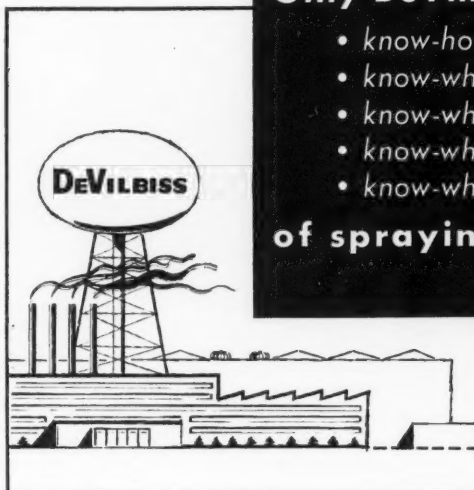
Total registration for the course was 162.

CORROSION's index appears in December.

### Only DeVilbiss brings the

- know-how
- know-what
- know-why
- know-when
- know-where

### of spraying to you!



### FIELD CONSULTANT SERVICE

Upon written request DeVilbiss will make available to Corrosion Engineers and Painting and Decorating Contractors, without cost or obligation, the services of a professional consultant to analyze methods, procedures, and equipment. His purpose is to help you get the most from the spray method in applying coatings of any type to structures or surfaces of any kind.

### FIELD TRAINING SCHOOL

Here at last is the opportunity to provide complete and thorough instruction at nominal cost on all phases of spray equipment and its use to supervisors and operators . . . *in your own local area*. No time need be lost from the job. School may be readily set up for "after hours" classes.

## Australian Essay Prize Awarded to NACE Member

NACE member Daniel B. Stauffer, senior engineer in the Production Department at Humble Oil and Refining Co., Houston, won the prize in the annual essay competition sponsored by the Australian Association for Corrosion Prevention.

His essay titled "Structural Design for Offshore Corrosion Control" originally was a paper presented at a meeting of the 1955 NACE South Central Region Conference held in Houston.

The prize awarded in the international contest was 50 guineas, about \$117. Purpose of the essay contest is to stimulate technical work in the corrosion field and to publish suitable es-

says. Publication of Mr. Stauffer's essay has not been scheduled yet.

Mr. Stauffer learned of the Australian contest from a news story which appeared in a 1958 issue of CORROSION.

He has been a member of NACE since 1954, has presented papers at regional meetings and is a member of Technical Committees T-1M and T-6D.

## Permian Basin Corrosion Tour to Be Sept. 23-25

The 8th Biennial Corrosion Tour sponsored by the Permian Basin Section has been scheduled for September 23-25 with headquarters at the Lincoln Hotel, Odessa, Texas.

Exhibits on the use of inhibitors, alloys, coatings and cathodic protection in oil and gas production operations are

planned. Emphasis will be on waterflood corrosion control.

Field trips are planned for registrants to visit locations exhibiting corrosion control practices and field results.

Registration fee will be \$20. Additional information can be obtained from Jack L. Ward, tour chairman, at Plastic Applicators, Inc., P. O. Box 2749, Odessa, Texas.



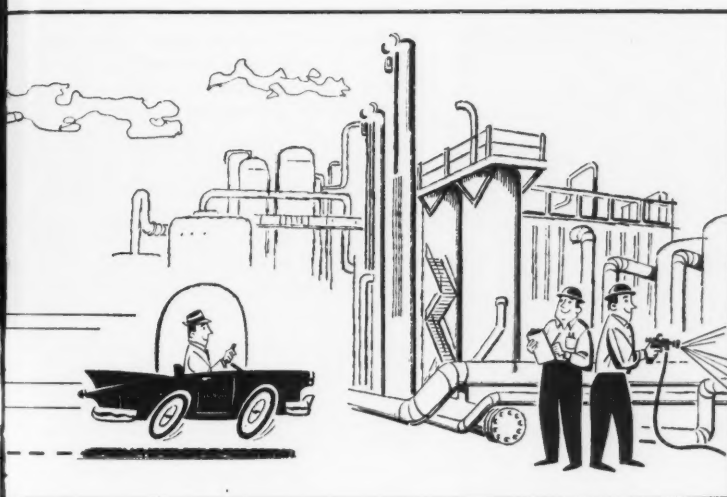
## SECTION CALENDAR

### August

- 27 Teche Section. Petroleum Club.
- 27 Edmonton Section

### September

- 4 Birmingham Section.
- 12 Corpus Christi Section. Annual Barbeque.
- 15 Chicago Section. Chicago Engineers Club.
- 15 San Joaquin Section.
- 16 Los Angeles Section
- 22 East Texas Section. Longview Hotel in Longview.
- 22 Baltimore-Washington Section. An Approach to Protective Coating Engineering, by Austin K. Long.
- 24 Edmonton Section
- 24 Teche Section. Petroleum Club.
- 28 Atlanta Section.



### Why these services are important to you

A noted coatings specialist recently stated: "When spray operators have the right equipment for the job and know how to use it properly, I've found the spray method is, by far, the best way to apply most protective and decorative coatings. It provides greater uniformity in film thickness. Coatings last longer, and can be applied considerably faster. But when spray equipment or operator training is inadequate, the many advantages of spraying are apt to be lost."

The problem is defined . . . and these new DeVilbiss services will help you solve it. To take advantage of either, write on your letterhead to: Director of Field Services, The DeVilbiss Co., Toledo 1, Ohio.



NACE PRESIDENT Hugh P. Godard of Aluminium Laboratories, Ltd., Kingston, Ontario, Canada, gave the key-note address at the 4th Annual Appalachian Underground Corrosion Short Course held June 2-4 on the West Virginia University campus at Morgantown. A total of 520 persons attended.

## Appalachian Short Course Has Record Attendance

Record attendance of 520 persons was reached at the 4th Annual Appalachian Underground Corrosion Short Course held June 2-4 on the West Virginia University campus at Morgantown. Registrants represented the United States, Canada and Cuba.

Lectures, motion pictures, exhibits and field demonstrations were included in the short course.

Officers for the 1960 short course are General Chairman C. M. Rutter, Equitable Gas Co., Program Chairman D. A. Tefankjian, Texas Eastern Transmission Corp., Exhibits Chairman G. G. Campbell, West Virginia University, Publicity Chairman John H. Alm, Dearborn Chemical Co., and Registration Chairman R. E. Hanna, Jr., West Virginia University.

General chairman for the 1959 short course was Charles L. Dey of the Koppers Company.

### THE DEVILBISS COMPANY

Toledo 1, Ohio

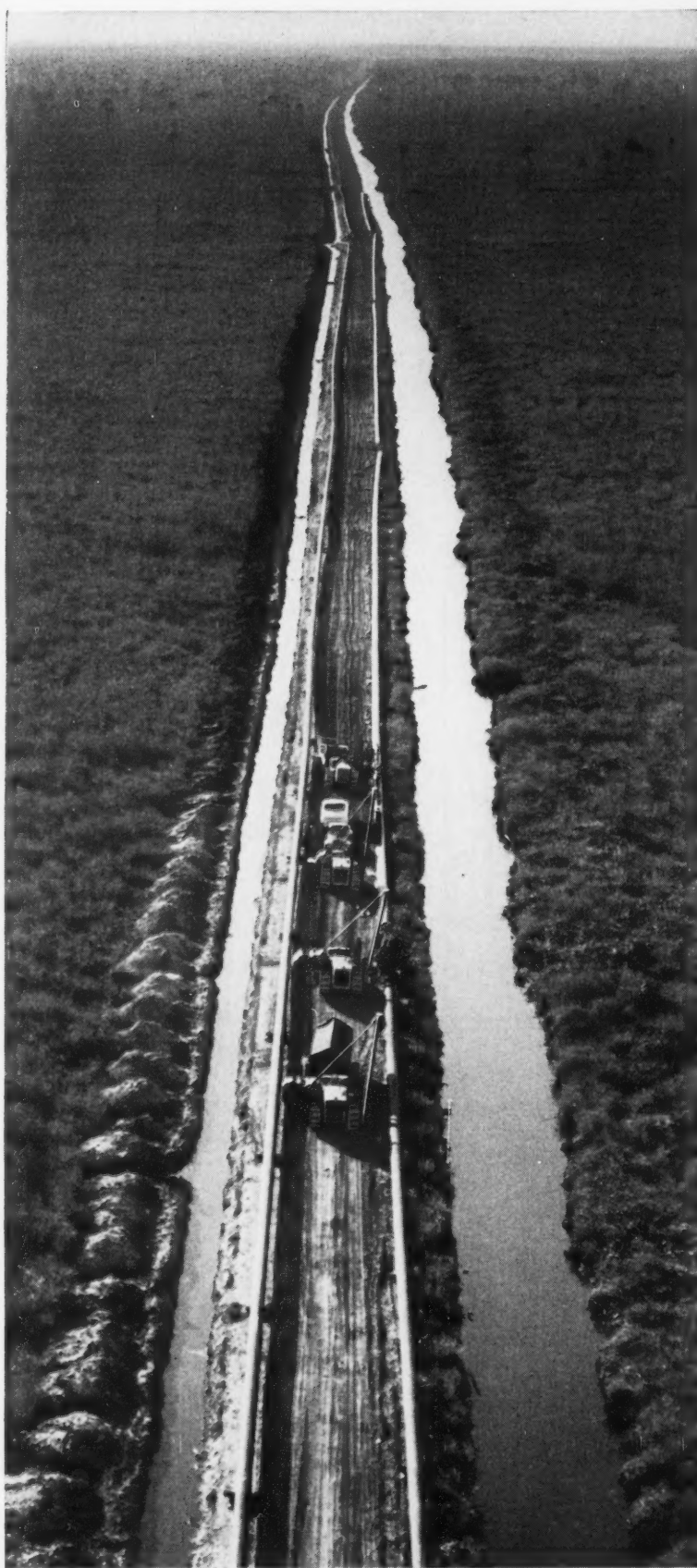
Barrie, Ontario • London, England  
São Paulo, Brazil

Branch Offices in Principal Cities

FOR BETTER SERVICE, BUY

**DEVILBISS**





## HOW TO CHECK OUT THE TOUGHEST TAPE EVER WRAPPED AROUND PIPELINE

Give it the works... that's what  
Polyken did to its latest development—  
Extra Strength No. 960

... Run it through every tape durability test a laboratory can apply.

... Wrap this rugged tape around 30 miles of 24-inch gas line in the swamp water and coral rock of southern Florida. Let an Iranian oil company use it on 200 miles of desert oil line. Put it to work for the Phillips Petroleum Co. in Texas and Canada.

If a tape coating can stand all this and still do the whole job cheaper than hot dope, you've got something special. Something permanent in pipeline protection—Polyken Extra Strength No. 960 Pipeline Roll.

*Available at no extra cost.*



Applying Polyken protection, as seen above, the Houston Texas Gas and Oil Corporation laid a 1600-mile gas line from Louisiana to Florida. Polyken saved them \$500 per mile by way of less men per job and more miles per day. Tape's ready. No primer, no drying or cooling, no fumes or fire hazard. And low equipment cost.

Get the full particulars on Polyken performance and economy from your Polyken representative or write Polyken Sales Division, 309 W. Jackson Blvd., Chicago 6, Ill.

# Polyken®

**Experienced in modern  
PROTECTIVE COATINGS**

THE KENDALL COMPANY  
Polyken Sales Division

PO  
PR  
CO  
DIS

Atla  
Steel

Chic  
Sales

Cinc  
Hare

Clev  
The k

Den  
Patte

Des  
Dono

For  
Plast

Harv  
Allen

Co

Hous  
Cath

Kan  
Indus

Long  
Barn

Mem  
Gene

Minn  
Simco

Phil  
Harv

Plain  
Stuar

St. L  
Shutt

San  
Incor

San  
Phillip

Seatt  
Farw

Seatt  
Pacifi



## Northeast Region News

### POLYKEN PROTECTIVE COATINGS DISTRIBUTORS

**Atlanta, Georgia**  
Steele & Associates, Inc.

**Chicago, Illinois**  
Sales Engineering Inc.

**Cincinnati, Ohio**  
Hare Equipment

**Cleveland, Ohio**  
The Harco Corp.

**Denver, Colorado**  
Patterson Supply

**Des Moines, Iowa**  
Donald Corporation

**Fort Worth, Texas**  
Plastic Engineering & Sales Corp.

**Harvey, La.**  
Allen Cathodic Protection  
Company, Inc.

**Houston, Texas**  
Cathodic Protection Service

**Kansas City, Missouri**  
Industrial Coatings Engineering Co.

**Long Beach, Calif.**  
Barnes & Delaney

**Memphis, Tenn.**  
General Pipe & Supply Co.

**Minneapolis, Minn.**  
Simcoe Equipment Co.

**Philadelphia, Pa.**  
Harold N. Davis Co.

**Plainfield, New Jersey**  
Stuart Steel Protection Corp.

**St. Louis, Missouri**  
Shutt Process Equipment Co.

**San Francisco, Calif.**  
Incandescent Supply Co.

**San Francisco, Calif.**  
Phillips & Edwards Electric Co.

**Seattle, Washington**  
Farwest Corrosion Control Corp.

**Seattle, Washington**  
Pacific Water Works Supply Co.

**Polyken**  
Experienced in modern  
PROTECTIVE COATINGS

Philadelphia Section planned a field trip aboard two U. S. Navy ships in the mothball fleet at the Philadelphia Navy Yard for its July 21 meeting. Discussions on protective coatings, dehumidification, cathodic protection and other related methods of preventing corrosion were to be discussed.

At the section's June 19 meeting, Norman Grooves presented a paper and slides on the types of failures of various alloys in the refining industry.

Baltimore-Washington Section has based its 1959-60 program on a poll taken to determine the corrosion interests of the section members. A program chairman for each meeting was selected for his interest in a specific field.

The four section meetings for 1959-60 with the speakers, their topics and the program chairman for each meeting are given below:

September 22: An Approach to Protective Coating Engineering, by Austin K. Long. Program chairman: T. E. Krehnbrink.

November 16: Problems, Testing and Mitigation Methods Peculiar to Corrosion Control of Lead Sheath Cables in Underground Multiple Ducts, by T. J. Maitland. Program chairman: H. L. Baer.

February 16, 1960: Corrosion Problems in Highway Maintenance, by W. J. Halstead. Program chairman: H. L. Logan.

April 19, 1960: Corrosion Preventive Measures Necessary in the Design and Construction of an Underground Pipeline, by E. C. Hine and R. E. Barrans. Program chairman: L. O. McCormick.

Genesee Valley Section scheduled regular election of officers for its June 23 meeting. The agenda also included discussion of amendments for the section by-laws and the regional meeting to be held in Rochester, N. Y.

1959 Northeast Region Conference will be held October 5-8 at the Lord Baltimore Hotel, Baltimore, Maryland.

Three technical committee meetings are scheduled for the Northeast Region Conference to be held October 5-8 at the Lord Baltimore Hotel, Baltimore, Md.

### 1959 Northeast Region Conference Program

A complete program of the '59 Northeast Region Conference (Oct. 5-8 in Baltimore, Md.) appears on pages 72 to 87. Included are schedule of events, technical program, abstracts of papers to be presented and photos and biographical sketches of authors.

Lapel pins approximately 7/16 inches high, made of gold with inlaid red enamel and a ruby center, are available to NACE members only. Price is \$10. Address orders to Executive Secretary, 1061 M & M Bldg., Houston 2, Texas.



PAST CHAIRMAN CERTIFICATE was presented to Walter Burton (left) of the Philadelphia Section. A. F. Minor, vice chairman of the Northeast Region, made the presentation at a recent section meeting.

## Western Region News

Portland Section had 12 speakers on its June 11 program who briefly described the products and services of the industrial firms which they represented. Pipe tapes, coatings, insulated couplings, paints and alloys were among the products discussed.

No meeting will be held in August. A regular section meeting is scheduled for September.

Puget Sound Section had a total enrollment of 115 at its May 21-22 short course on corrosion control held at Seattle University. Topics included theory of corrosion, coatings and cathodic protection.

Los Angeles Section heard Loren L. Neff speak on control of internal corrosion in tank ships at the May 13 dinner meeting.

Harry Kipps of Signal Oil and Gas Company is the section's vice chairman to replace B. E. Black, who has been transferred to Plicoflex's Houston, Texas, office.

Meeting dates for 1959-60 have been set for Sept. 16, Nov. 18, Jan. 20, March 23 and May 18.

### 1959 Western Region Conference Program

Schedule of the technical program, abstracts of papers and photos and biographical sketches of authors for the 1959 Western Region Conference (Sept. 29-Oct. 1 in Bakersfield, Cal.) appear on pages 88 to 93.

## Canadian Region News

Edmonton Section heard J. G. Parr of the University of Alberta speak on stress corrosion at the June 25 section meeting.

August 27 and September 24 are dates for the next two meetings.

# Oct. 5-8 Northeast Region Conference Program

## 35 Papers and 3 Plant Visits To Be Featured in Program

The 1959 Northeast Region Conference, to be held October 5-8 at the Lord Baltimore Hotel in Baltimore, Md., will feature 35 papers and 3 plant visits in the technical program.

The technical papers will be presented in seven symposia. A complete program including meeting times and hotel rooms is given below.

### Technical Committee Meetings

Five technical committee meetings will be held during the conference: T-3G, Cathodic Protection, T-2K-3, History and Results, Prefabricated Film for Pipe Line Coatings, T-4F-1 Materials Selection in the Water Industry, T-3F, Corrosion by High Purity Water and T-3G-1, Cathodic Protection of Hull Bottoms of Ships. All technical committee meetings will be held in the Phoenix Room of the Mt. Vernon Wing.

### Ladies Program

Luncheons, coffee hours and tours of Baltimore and surrounding points of interest have been planned for the ladies activity during the conference.

Other special conference activities include an oyster roast on Monday, October 5 and a banquet on Tuesday, October 6.

## Northeast Region Conference SCHEDULE OF EVENTS

### SUNDAY, October 4

PM

- 12-5 Registration, Ballroom Foyer
- 2 Northeast Region Conference Chairmen, Maryland Room
- 4 Northeast Region Board of Trustees, Maryland Room

### MONDAY, October 5

AM

- 7:30 Authors' Breakfast, Maryland Room
- 8-5 Registration, Ballroom Foyer
- 9:30 Ladies Coffee Hour, Parlor H Mezzanine
- 9:30 Conference Opening, Ballroom
- 10:15-12:30 Theory of Corrosion Symposium, Ballroom
- 10:15 Committee T-3G (Cathodic Protection), Mt. Vernon Wing

PM

- 12:30 Ladies Luncheon, Hutzlers
- 2-5 High Temperature Symposium, Ballroom
- 2-5 Cathodic Protection Symposium Part 1, Founder's Room
- 2 Committee T-2K-3 (History and Results), Mt. Vernon Wing
- 2:30 Ladies Tour of Baltimore
- 6:30 Oyster Roast

### TUESDAY, October 6

AM

- 7:30 Authors' Breakfast, Maryland Room
- 8-5 Registration, Ballroom Foyer
- 9-12 Protective Coating Symposium Part 1, Founder's Room
- 9-12 Educational Film, Mt. Vernon Wing
- 9-12 Handling Water Symposium, Ballroom
- 10 Ladies Bus Tour of Annapolis

PM

- 12:30 Nuclear Reactor Visit
- 1:30 Baltimore Works, Armco Steel Corporation Visit
- 1:45 Southern Galvanizing Company Visit
- 2 Committee T-4F-1 (Materials Selection in the Water Industry), Mt. Vernon Wing
- 6:30 Fellowship Hour, Founder's Room
- 7:30 Banquet, Ballroom

### WEDNESDAY, October 7

AM

- 7:30 Authors' Breakfast, Maryland Room
- 8-2 Registration, Ballroom Foyer
- 9-12:30 Protective Coatings Symposium Part 2, Ballroom
- 9-12 Education Film, Mt. Vernon Wing
- 9:30 Ladies Coffee Hour, Parlor H Mezzanine

PM

- 2-5 Special Topics Symposium Part 1, Ballroom
- 2-5 Inhibitor Symposium, Founder's Room
- 2 Committee T-3F (Corrosion by High Purity Water), Mt. Vernon Wing

### THURSDAY, October 8

AM

- 7:30 Authors' Breakfast, Maryland Room
- 9 Committee T-3G-1 (Cathodic Protection of Hull Bottoms of Ships), Mt. Vernon Wing
- 9-12 Cathodic Protection Symposium Part 2, Ballroom
- 9-12 Special Topics Symposium Part 2, Founder's Room

## Northeast Region Conference TECHNICAL PROGRAM

### MONDAY, October 5

#### BALLROOM

AM

9:30

#### Welcome and Introductory Remarks

- Kenneth M. Huston, Co-Chairman 1959 Regional Conference
- George E. Best, Vice President, NACE
- G. A. Rolak, Administrative Assistant, NACE Headquarters
- F. E. Costanzo, NACE Director Representing Northeast Region
- H. S. Preiser, Chairman, Technical Program

### Theory & Principles Symposium

CHAIRMAN FRED REINHART, Supervising Research Engineer, Division of Metallurgy, National Bureau of Standards, Washington, D. C.

10:15

- 1 Theory of Bimetallic Corrosion, by M. J. Pryor, Metals Research Laboratories, Olin Mathieson Corp., New Haven, Conn.

11

- 2 Theory of Stress Corrosion Cracking, by H. R. Copson, Research Laboratories, International Nickel Co., Inc., Bayonne, N. J.

11:45

- 3 Electrochemistry of Pitting Corrosion, by N. D. Greene, Union Carbide Metals Co., Niagara Falls, N. Y.

### Cathodic Protection Symposium Part 1, Marine

CHAIRMAN SIDNEY TUDOR, Supervisory Chemist, Electrochemistry Unit, Material Laboratory, New York Naval Shipyard, Brooklyn, N. Y.

PM

2

- 4 Service Test Experience With an Automatically Controlled Platinum Anode Cathodic Protection System of an Active Destroyer, by R. C. Francis and L. S. Birnbaum, Bureau of Ships, Navy Department, Washington, D. C.

(Continued on Page 74)

**Propane-soluble  
additive**

**UNICOR LHS®**

*proves superior as detergent,  
corrosion inhibitor  
or anti-icer!*

Added to your gasoline as anti-icer, UNICOR LHS does an effective job in preventing carburetor icing and consequent stalling. In addition, UNICOR LHS imparts greater detergency to your gasoline than the best competing additives—and at lowest cost.

But in addition to improving the quality, and hence the salability, of your gasoline, UNICOR LHS performs these money-saving services for you:

A surface active additive, soluble in all hydrocarbons including liquid propane, UNICOR LHS safeguards pipelines and refinery equipment against corrosion. It is also a highly effective detergent—eliminates troublesome deposits in heat exchangers, promotes cleanliness of refinery equipment.



*Get the facts about this superior  
triple-purpose additive today. Write  
or phone our Products Department  
for information and samples.*

**UNIVERSAL OIL PRODUCTS COMPANY**



**30 Algonquin Road,  
Des Plaines, Ill., U.S.A.**



## Northeast Region Conference TECHNICAL PROGRAM

(Continued From Page 72)

PM  
2:45

- 5 **Electrical Significance of Cathodic Protection on Hazardous Area Steel Docks**, by T. A. Mullett and J. W. Johnstone, Jr., Atlantic Refining Corp., Inc., Philadelphia, Pa.

3:30

- 6 **Some Studies on the Effects of Cathodic Protection on Cavitation Damage**, by B. H. Tytell and R. L. Burnett, Boston Naval Shipyard, Boston, Mass., and H. S. Preiser, Bureau of Ships, Navy Department, Washington, D. C.

4:15

- 7 **Effect of Impurity Elements and Water Velocity on Performance of Zinc, Aluminum-Zinc and Magnesium Alloy Anodes**, by J. L. Basil, U. S. Naval Engineering Experimental Station, Annapolis, Md.

### FOUNDER'S ROOM

#### High Temperature Corrosion Symposium

CHAIRMAN HUGH L. LOGAN, Physicist, National Bureau of Standards, Washington, D. C.

PM  
2

- 8 **Combating Oil-Ash Corrosion in Navy Boilers**, by B. B. Rosenbaum, Bureau of Ships, Navy Department, Washington, D. C.

3:30

- 9 **Some Observations on Effect of Caustic Solutions on Corrosion of Steel at 316 C**, by M. C. Bloom and W. A. Fraser, Naval Research Laboratory, Washington, D. C.

4:15

- 10 **Studies of Elevated Temperature Corrosion of Type 310 Stainless Steel by Vanadium Compounds**, by H. L. Logan, National Bureau of Standards, Washington, D. C.

TUESDAY, October 6

### FOUNDER'S ROOM

#### Protective Coatings Symposium Part 1

CHAIRMAN LEON BIRNBAUM, head, Preservation, Decking & Insulation Section, Navy Department, Bureau of Ships, Washington, D. C.

AM  
9

- 11 **Structure and Characteristics of Hot-Dip Galvanized Coatings**, by H. R. Breslau, Southern Galvanizing Corp., Baltimore, Md.

9:45

- 12 **100% Non-Volatile Sprayable Epoxy Resins**, by W. C. Naumann, Shell Oil Corp., Union, N. J.

10:30

- 13 **Coating Performance by Statistical Means**, by F. E. Cook and A. S. Marthens, Bureau of Ships, Navy Department, Washington, D. C.

11:15

- 14 **Coal Tar Emulsion Coatings**, by W. E. Kemp and J. J. Lane, Koppers Co., Inc., Verona, Pa.

### BALLROOM

#### Corrosion in Handling Water Symposium

CHAIRMAN SHEPPARD T. POWELL, Senior Partner, Sheppard T. Powell & Associates, Baltimore, Md.

AM  
9

- 15 **Chromium Electroplates for Corrosion Protection of Stressed AISI 410 in High Temperature, High Purity Water**, by H. Suss, Knolls Atomic Power Laboratory, Schenectady, N. Y.

9:45

- 16 **Leaching Action of Various Materials by High Purity Water**, by E. L. Knoedler and J. B. Goodson, Jr., Sheppard T. Powell & Associates, Baltimore, Md.

10:30

- 17 **Power Plant Corrosion**, by Piero Sturla, Societa Edisonvolta S.p.A., Milano, Italy

11:15

- 18 **Applications of Aluminum Alloys for Handling Sea Water and Condensate**, by R. L. Horst, Aluminum Company of America, New Kensington, Pa.

WEDNESDAY, October 7

### BALLROOM

#### Protective Coatings Symposium Part 2

AM  
9

- 19 **Marine Corrosion in Ships**, by R. S. Capp, U. S. Coast Guard, 8th District, New Orleans, La., and B. J. Philibert, Pittsburgh Chemical & Coke Corp., Baltimore, Md.

9:45

- 20 **Protection of Ship Hulls Against Corrosion**, by B. J. Philibert and R. S. Capp

10:30-12:30

- 21 **Round Table Discussion—Role of Recently Developed Resins in Corrosion Control**

- 21a **Epoxies**, by H. H. Flegenheimer, Devoe and Reynolds, Newark, N. J.

- 21b **Use of Polysulfides in Coatings**, by P. W. Atkinson, Thiokol Chemical Corp., Trenton, N. J.

- 21c **Recent Developments in Vinyl and Vyn-Al Coatings**, by R. P. Devoluy, Glidden Paint Co., New York, N. Y.

- 21d **Urethane Coatings**, by S. N. Ephraim, Reichhold Chemical Corp., Elizabeth, N. J.

- 21e **Inorganic Zinc Silicate Coatings**, by W. A. Guerry, Amercoat Corp., Kennilworth, N. J.

- 21f **Role of New Resins as Linings of Petroleum Fuel Storage Tanks**, by J. E. Cowling, Naval Research Laboratory, Washington, D. C.

#### Special Topics Symposium Part 1

CHAIRMAN CARL J. WESSEL, Director, Prevention of Deterioration Center, National Academy of Sciences, Washington, D. C.

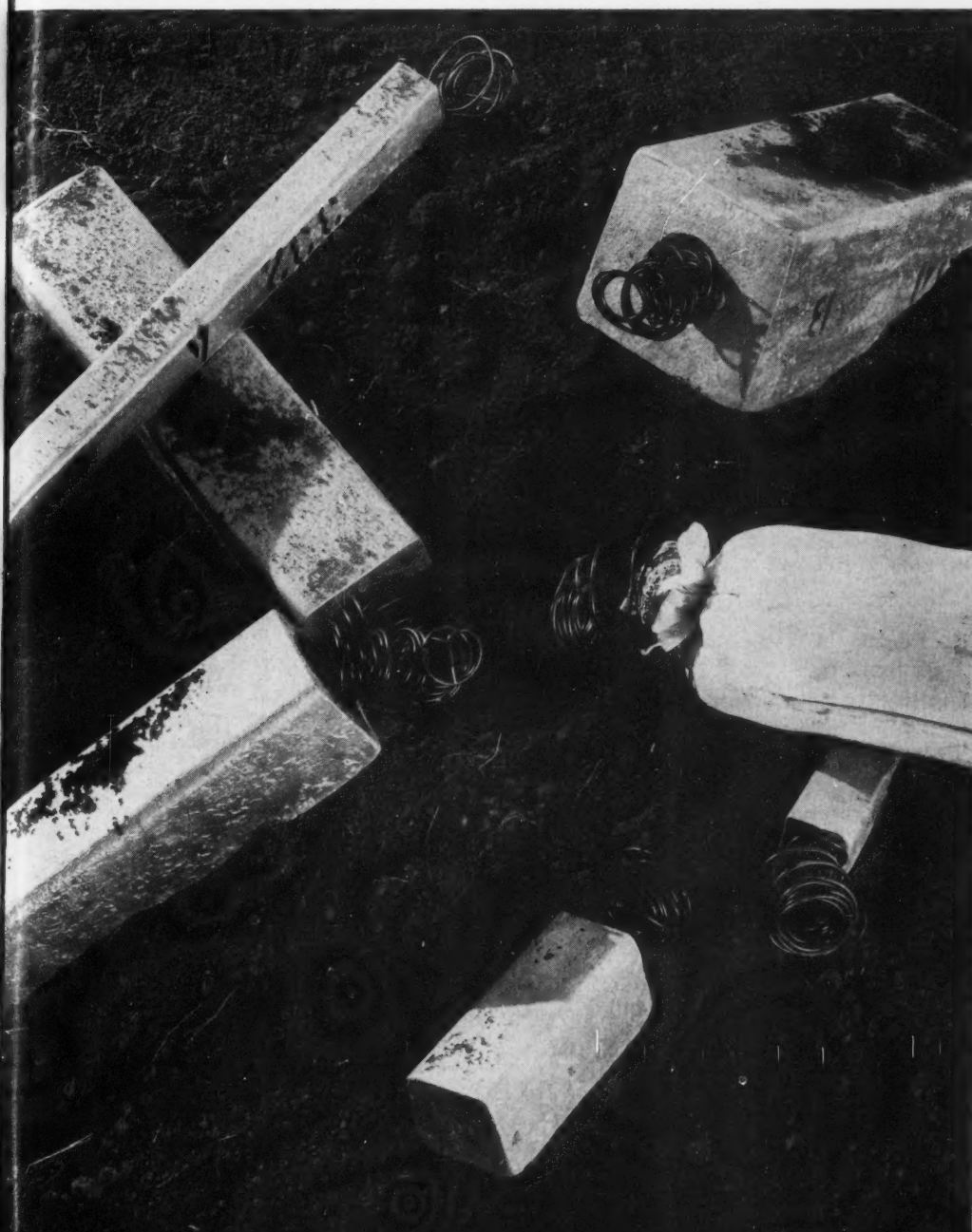
PM  
2

- 22 **Effect of Composition and Heat Treatment on the Stress Corrosion Cracking of Stainless Steels**, by E. E. Denhard, Jr., Research Laboratories, Armco Steel Corp., Baltimore, Md.

(Continued on Page 76)

*No other supplier offers you as many materials* or as much practical experience in corrosion control. Federated's Corrosion Advisory Service can recommend the best for you from among GALVANIC ANODES, magnesium and zinc; LEAD SHEET, PIPE, and FITTINGS; ZINC and ZINC ALLOYS for galvanizing; ZINC DUST; COPPER and ALLOYS; and PLATING MATERIALS, including copper, lead, cadmium, zinc, and silver anodes; nickel salts and addition agents for plating baths. One of Federated's 22 sales offices is near you. Don't hesitate, call us with your corrosion problems . . . no obligation, of course. Federated Metals Division, 120 Broadway, New York 5. In Canada: Federated Metals Canada, Ltd., Toronto and Montreal.

## FEDERATED METALS DIVISION OF



# ASAARCO

AMERICAN SMELTING AND REFINING COMPANY

## Northeast Region Conference TECHNICAL PROGRAM

(Continued From Page 74)

- 2:45 23 Stress Corrosion Cracking of Austenitic Stainless Steel in Uranyl Sulfate Solutions, by J. L. English and J. C. Griess, Oak Ridge National Laboratory, Oak Ridge, Tenn.
- 3:30 24 Review and Current Status of Bacterial Corrosion, by R. L. Starkey, Rutgers University, New Brunswick, N. J.
- 4:15 25 Interference Aspects of Forced Drainage Installations Designed to Mitigate Corrosion of Underground Cables and Pipes, by S. C. Miller, Chesapeake & Potomac Telephone Co., Baltimore, Md.

### FOUNDER'S ROOM

#### Corrosion Inhibitors Symposium

CHAIRMAN ALFRED DOUTY, Technical Director, Amchem Products, Inc., Ambler, Pa.

- PM  
2 26 Applications of Corrosion Inhibitors in the Steel Industry, by E. H. Phelps, Applied Research Laboratory, U. S. Steel Corp., Monroeville, Pa.
- 2:45 27 Inhibitors for Phosphoric Acid, by A. O. Fisher, Monsanto Chemical Co., St. Louis, Mo.
- 3:30 28 Researches on Corrosion and Inhibitors: Reaction Velocity in Corrosion of Iron by Aqueous Hydrogen Sulfide and the Effect of Inhibitors, by G. S. Gardner, Amchem Products, Inc., Ambler, Pa.
- 4:15 29 General Discussion of the Use of Corrosion Inhibitors in Automotive Applications, by L. C. Rowe, General Motors Research Laboratories, Detroit, Michigan

THURSDAY, October 8

### BALLROOM

#### Cathodic Protection Symposium Part 2—General

- AM  
9 30 Cathodic Protection of Steel-Hydrogen Embrittlement Studies, by W. H. Bruckner, University of Illinois, and K. M. Myles, Argonne National Laboratory, Chicago, Ill.
- 9:45 31 Properties and Applications of Platinum Coated Anodes, by C. E. Tirrell, Ionics, Inc., Cambridge, Mass.
- 10:30 32 Preparation and Properties of a Stable Silver-Silver Chloride Electrode for Use in Sea Water, by M. H. Ortnier, Vitro Laboratories, West Orange, N. J.
- 11:15 33 Design Problems in Applying Permanent Cathodic Protection to Glass Lined Water Heaters, H. C. Fischer, Thermo-Craft Corp., Montville, N. J.

### FOUNDER'S ROOM

#### Special Topics Symposium Part 2

- AM  
9 34 The Pentagon Story of Cathodic Protection, by L. A. Major, Chesapeake & Potomac Telephone Co., Washington, D. C.
- 9:45 35 Corrosion of a Single Crystal of Aluminum, by T. H. Orem, National Bureau of Standards, Washington, D. C.

### INDUSTRIAL MOTION PICTURE FILMS

#### MOUNT VERNON WING

TUESDAY, October 6, and WEDNESDAY, October 7

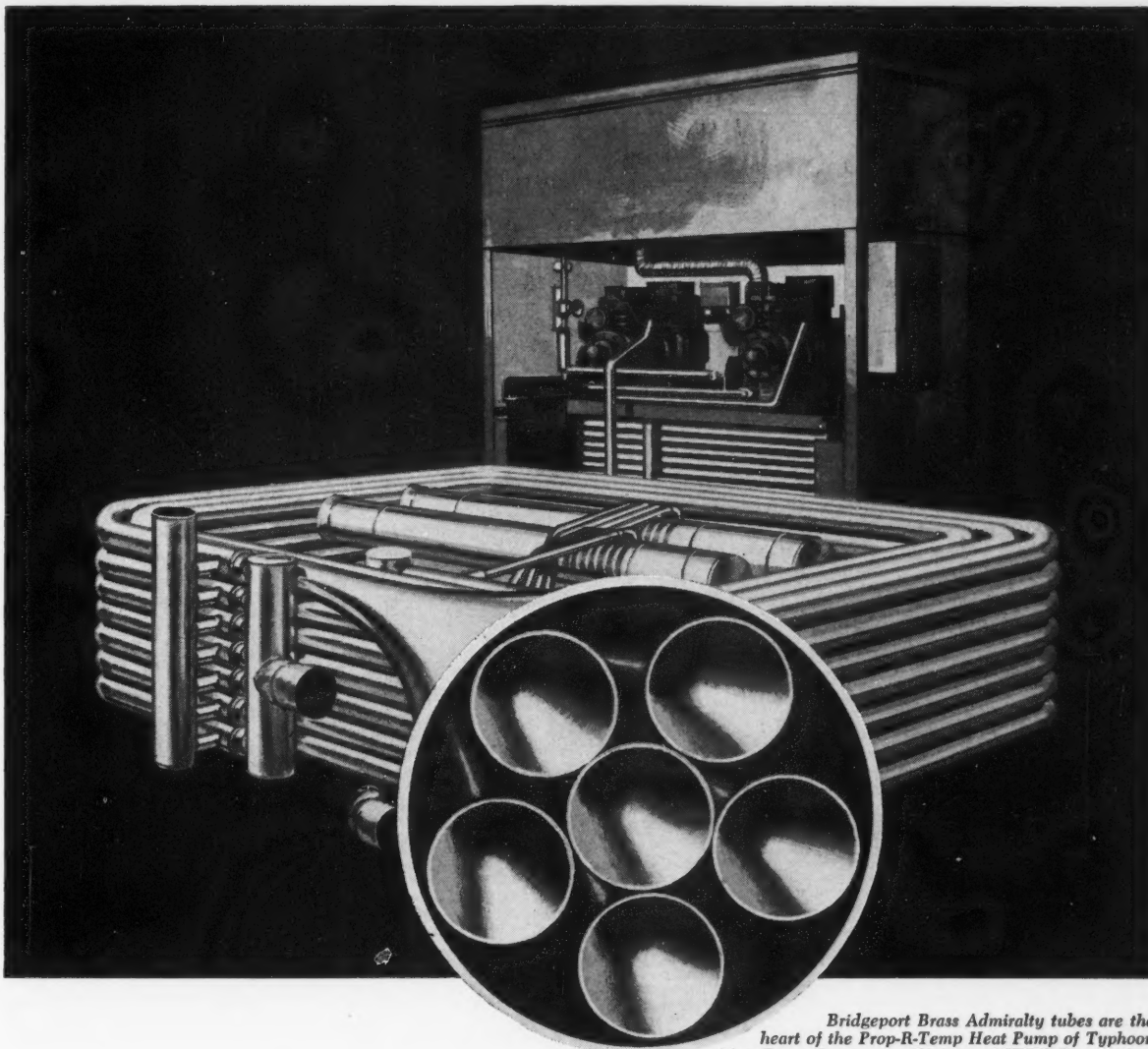
- 9:30 am Naval Research Laboratory Reactor. A color film description of this facility. An excellent picture for those unable to make the trip and a review for those who visited the facility.
- 10 am Steel Spans the Chesapeake. (Bethlehem Steel Company) Building the four-mile, \$44,000,000 bridge across Chesapeake Bay.
- 10:45 am Refining Copper From Sudbury Ores. (International Nickel Co., Inc.) The nickel company's color motion picture describes the extraction and refining of copper from their Canadian ores.

### ABSTRACTS

- 1 Theory of Bimetallic Corrosion by M. J. Pryor, Olin Mathieson Corp., New Haven, Conn.  
Review present theories of bimetallic corrosion and subdivides experimental observations into two classes: (a) galvanic corrosion involving metals which behave in reversible fashion and (b) galvanic corrosion of metals which behave in an irreversible fashion. Aluminum is used as the example because both anodic and cathodic reactions occur at potentials widely different from the corrected Nernst potential. Aluminum's irreversible nature as a cathode is related to high ohmic resistance of surface oxide film which at low current densities permits easy passage of electrons only at locations reflecting imperfections in underlying metal due to causes such as grain boundaries, edge dislocations, etc. As an anode, aluminum exhibits a field limiting behavior because of a thin dielectric oxide film. This behavior is similar to that during anodizing aluminum in non-solvent electrolytes except that leakage currents are much higher. This aspect of irreversible anodic behavior is illustrated by experiments on aluminum-iron galvanic couple.
- 2 Theory of Stress Corrosion Cracking by H. R. Copson, International Nickel Co., Inc., Bayonne, N. Y.  
Defines stress corrosion cracking and classifies kinds of cracking as failures involving stress-sorption cracking and as failures involving mechanical factors. Reviews principal electrochemical mechanisms.
- 3 Electrochemistry of Pitting Corrosion by N. D. Greene, Electro Metallurgical Corp., Niagara Falls, N. Y.  
Modern theories of pitting corrosion are discussed with relation to recent experimental results. Influence of environmental variables on pit growth characteristics is described. A new concept of electrochemical action during pitting, based on mixed potential theory, is proposed.
- 4 Service Test Experiences With an Automatically Controlled Platinum Anode Cathodic Protection System of an Active Destroyer by R. C. Francis and L. S. Birnbaum, Bureau of Ships, Navy Department, Washington, D. C.  
Discusses an automatically controlled platinum anode system used on a destroyer to maintain hull potentials within close values for an 18-month period. Corrosion was virtually eliminated during the service trial aside from some operational difficulties.
- 5 Electrical Significance of Cathodic Protection on Hazardous Area Steel Docks by T. A. Mullett and J. W. Johnstone, Atlantic Refining Corp., Inc., Philadelphia, Pa.  
Report is given on test data concerning electrical situation at cathodically protected docks in petroleum service where hazardous atmospheres may exist such as ships, setting up conductor by which current can flow. Effect of rectifier operation while the ship is at dock is given. Results and conclusions of investigations are given of arc energy for the magnitudes encountered at cathodically protected steel docks.
- 6 Some Studies on the Effects of Cathodic Protection on Cavitation Damage by B. H. Tytell, Boston Naval Shipyard, Boston, Mass., R. L. Burnett, Boston Naval Shipyard, and H. S. Preiser, Bureau of Ships, Navy Department, Washington, D. C.  
Experiments are described showing the reduction of cavitation damage on manganese bronze and steel by applied cathodic currents. Current densities used are higher than those associated with cathodic protection of structures and ships. Outlines cavitation producing equipment used and discusses methods by which cavitation collapse on test specimen were ascertained. Reviews briefly mechanisms of cavitation with emphasis on how damage is thought to occur. New postulations are made on electrochemical aspects of cavitation damage and protection.

(Continued on Page 78)





Bridgeport Brass Admiralty tubes are the heart of the Prop-R-Temp Heat Pump of Typhoon Heat Pump Company, a Division of HUPP Corporation.

# 1,000 HEAT PUMPS PROVE THE DEPENDABILITY OF BRIDGEPORT TUBES

This remarkable Prop-R-Temp Heat Pump, a product of Typhoon Heat Pump Company, Tampa, Florida, heats, cools and dehumidifies. A key part of this unit is the tube-in-tube condenser coil which transfers heat from water to refrigerant, or reverse. This unique circular or rectangular coil consists of six  $\frac{3}{8}$ " O D Bridgeport Admiralty tubes nestled inside a larger, 1 $\frac{1}{2}$ " O D Admiralty tube. The six smaller tubes are inserted into a straight length of larger tube and then coiled or bent on blocks of various radii. This fabricating method requires closely controlled physical properties of tube to avoid distortion. The length and number of coils—whatever their size—is subjected to a test of 1,000 lbs. pressure before being accepted for application.

Years ago, trouble was frequently experienced due to copper tube failure or excessive scaling caused by highly corrosive waters in certain localities. This failure was costly since, when it occurred, it was necessary to replace the entire condenser.

Bridgeport came up with the answer—Admiralty tubes. Since the switch, over 1,000 Typhoon heat pumps have gone into service without one instance of tube failure due to corrosion in sizes varying up to 1,000,000 BTU's.

Here again is an example of how *standard* Bridgeport alloys overcame *special* fabricating and corrosion problems. It's also an example of why it pays to take advantage of Bridgeport's outstanding metals know-how. Call in the Man from Bridgeport, today. There's a Sales Office near you. Or write to Dept. 5804.

## BRIDGEPORT BRASS COMPANY

Bridgeport 2, Connecticut • Sales Offices in Principal Cities  
Specialists in Metals from Aluminum to Zirconium



## Northeast Region Conference TECHNICAL PROGRAM

(Continued From Page 76)

**7 Effect of Impurity Elements and Water Velocity on Performance of Zinc, Aluminum-Zinc and Magnesium Alloy Anodes** by J. L. Basil, U. S. Engineering Experimental Station, Annapolis, Md.

Comparison is given of behavior in natural sea water of aluminum alloy XB605, magnesium alloy AZ-63 and high purity zinc anodes. Current output of aluminum alloy decreases as the iron content increases. Copper has no significant effect on current output of magnesium alloy. Corrosion rate and current output are higher in moving than in quiescent sea water, but galvanic efficiency is unchanged.

**8 Combatting Oil Ash Corrosion in Navy Boilers** by B. B. Rosenbaum, Bureau of Ships, Navy Department, Washington, D. C.

Catastrophic attack of superheater components in Navy boilers by molten sodium vanadate slags from combustion of residual fuel oils is discussed. Examples of failure of Type 310 alloy superheater tube supports in less than 2000 steaming hours are cited. Describes in detail the Navy's research and development program to prevent or control such attack. Studies given include superheater design, fuel additive treatments, protective coatings and new resistant materials such as alloys, cermets and ceramics. Also gives details of an experimental alloy and results of fundamental research on the mechanism of sodium vanadate attack.

**9 Some Observations on Effect of Caustic Solutions on Corrosion of Steel at 316 C** by W. A. Fraser and M. C. Bloom, U. S. Naval Research Laboratory, Washington, D. C.

The Hydrogen effusion method developed for measurement of corrosion rates at elevated temperatures and pressure has been applied to the examination of the effect of NaOH upon the rate and nature of attack on mild steel at 316 C. Results of experiments with solutions of concentrations to 40% NaOH are described.

**10 Studies of Elevated Temperature Corrosion of Type 310 Stainless Steel by Vanadium Compounds** by H. L. Logan, National Bureau of Standards, Washington, D. C.

Describes an investigation made of the attack at elevated temperatures of Type 310 stainless steel by vanadium compounds. Effects of atmospheres such as moist and dry air and helium on the type and intensity of attack have been studied. Microscopic examinations of the interface between the steel and solid compound (slag) have been made also. Results of spectrochemical analyses of the slag and steel and X-ray diffraction data on the slag are given.

**11 Structures and Characteristics of Hot-Dip Galvanized Coatings** by H. R. Breslau, Southern Galvanizing Co., Baltimore, Md.

Discusses factors which affect the physical and metallurgical structures and characteristics of the iron-zinc alloys basic to hot-dip galvanizing after fabrication method as distinguished from the controlled thickness coatings produced by continuous sheet and strip lines or the wire lines of steel mills.

**12 100% Non-Volatile Sprayable Epoxy Coatings** by W. C. Naumann, Shell Chemical Corp., Union, N. J.

Presents survey of recent work to meter and mix epoxy resins and curing agents so they can be sprayed like conventional coatings. Also discusses formulation developments that have produced highly chemical resistant, flexible epoxy coatings. These coatings, free of solvent, presents no danger from fire or health standpoints and are easily applied in heavy film thicknesses in one operation.

**13 Coating Performance by Statistical Methods** by F. E. Cook and A. S. Marthens, Bureau of Ships, Navy Department, Washington, D. C.

Report is given on exposure test of painted steel drums at Kure Beach, North Carolina. Comparison is made of four paint formulations: one and two coat applications, in two colors on four different types of steel surface treatments. A method of evaluating the condition of paint on steel is described and its use is illustrated by tests of painted steel drums. Statistical analysis of the data provides assurance of correct interpretation of the results.

**14 Coal Tar Emulsion Coatings** by W. E. Kemp and J. J. Lane, Koppers Company, Inc., Verona, Pa.

Discusses emulsions formulated from coal tar, fillers and water as barrier coatings, as top coat for other bituminous coatings and as seal coating for asphalt and concrete surfaces against deteriorating effects of fuel spillage and de-icing salts. New modifications of coal tar base with polymeric materials and new pigments has developed emulsion coatings with outstanding physical and chemical resistance. Examples of each type and their serviceability in a variety of corrosive environments and applications are discussed.

**15 Chromium Electroplates for Corrosion Protection of Stressed AISI 410 in High Temperature, High Purity Water** by H. Suss, Knolls Atomic Power Laboratory, Schenectady, N. Y.

Presents variations in results obtained on use of chromium plate for protection of AISI 410 (RC 36-42, tempered at 650 F) against stress corrosion cracking on exposures to various high temperature waters at 300 F. Bases for variations are discussed. Value of chromium plate for protection of soft (RC 20-30, tempered at 1125 minimum) AISI 410 against pitting attacks in oxygenated water is also given.

**16 Leaching Action of Various Materials by High Purity Water** by E. L. Knoedler and J. B. Goodson, Jr., Sheppard T. Powell & Associate, Baltimore, Md.

There must be a minimum of contamination of high purity water by leaching action upon materials in contact. This may be of greater importance than protection of the materials. Many materials have been tested to determine their suitability for this service. Coating in contact with such waters have received special attention. Increasing interest in condensate scavenging for modern steam generators adds to the importance of data in this field.

**18 Applications of Aluminum Alloys for Handling Sea Water and Condensate** by R. L. Horst, Aluminum Company of America, New Kensington, Pa.

Discusses aluminum applications for saline water equipment and suitability of these applications. Also discusses corrosion design considerations and service experience.

**19 Marine Corrosion in Ships** by R. S. Capp, U. S. Coast Guard, New Orleans, La., and B. J. Philibert, Pittsburgh Chemical & Coke Corp., New Orleans, La.

Marine corrosion in ship hulls is a major cause of severe maintenance costs. Many areas which are most heavily attacked are difficult to reach. Sometimes extent of corrosion is not observed until perforation of metal occurs. Except

for mechanical damage as in a collision, most perforations in hulls proceed from inside to outside. Severe corrosion appurtenances and attachments is a continuing problem.

**20 Protection of Ship Hulls Against Corrosion** by B. J. Philibert, Pittsburgh Coke & Chemical Corp., New Orleans, La., and R. S. Capp, U. S. Coast Guard, New Orleans, La.

Conventional drying oil paints and oleoresinous materials have not been a satisfactory answer to the continuing problem of adequate protection of ship hulls against corrosion. Vinyls, coal tar epoxies and catalyzed epoxies provide longer term protection and in many cases solve the severe corrosion problem completely. Vapor-sealing mastic insulation based on Gilsolite now provides corrosion protection of steel under the insulation.

**21a Epoxies** by H. H. Flegenheimer, Devco and Reynolds, Newark, N. J.

Reviews recent developments in epoxy coatings including current uses of coatings in appliances, automotive, industrial maintenance and marine applications. Discussions are included of novel application techniques such as thick film coatings, fluidized bed coatings, coal tar epoxies and 100% N.V. spray coatings.

**21b Use of Polysulfides in Coatings** by P. W. Atkinson, Thiokol Chemical Corp., Trenton, N. J.

Five coating systems in which polysulfides are used will be discussed: liquid polymer-epoxy resin combinations, reverse phase types, liquid polymer paints, water dispersed system and flame spray powder.

**21c Recent Developments in Vinyl and Vyn-Al Coatings** by R. P. Devoluy, Glidden Paint Co., New York, N. Y.

Discusses recent formulation improvements which have made the vinyls easier to apply and to a greater film thickness per coat. Also includes vinyl-alkyds which have shown good gloss and color retention.

**21d Urethane Coatings** by S. W. Ephraim, Reichold Chemical Corp., Elizabeth, N. J.

Discusses characteristic and properties of urethane coatings and the four basic types. Baked urethanes and curing at atmospheric temperatures are included. Briefly reviews the limited literature on urethanes.

**21e Inorganic Zinc Silicate Coatings** by W. A. Guerry, Americoat Corp., Kenilworth, N. J.

Includes discussions on the chemical and physical properties of zinc silicate coatings with typical uses and results. Examples of industrial experience will include uses of the coating in the petroleum, water works, chemical and marine industries.

**21f Role of the New Resins as Linings of Petroleum Fuel Storage Tanks** by J. E. Cowling, Naval Research Laboratory, Washington, D. C.

Presents laboratory evaluation of polysulfide elastomers of organic film-forming polymers as linings of fuel storage tanks. An aqueous dispersion of a polysulfide elastomer with the copolymer of the vinylidene chloride or of the acrylonitrile has proved most suitable for use in concrete tanks. Discusses research to develop satisfactory linings for all types of fuel storage structures which can be applied without the use of hazardous thinners.

**22 Effect of Composition and Heat Treatment on Stress Corrosion Cracking of Austenitic Stainless Steels** by E. E. Denhard, Jr., Armo Steel Corp., Baltimore, Md.

Describes development of a multiple notch tensile test to investigate stress corrosion cracking in boiling 42% magnesium chloride. Samples were exposed at various applied stresses in both liquid and vapor phases until fracture occurred.

Effect of alloy composition was investigated by varying individual elements in an 18% Cr-12% Ni matrix. Results obtained by varying the significant elements are given.

Results of several test procedures used are discussed in comparison with current theories on stress corrosion cracking.

**23 Stress Corrosion Cracking of Austenitic Stainless Steel in Uranyl Sulfate Solution** by J. L. English and J. C. Griess, Oak Ridge National Laboratory, Oak Ridge, Tenn.

Discusses effects of variables on stress corrosion cracking behavior of austenitic stainless steel Type 347 in a simulated aqueous homogeneous reactor fuel solution. Results show sensitivity to cracking was independent whether solutions were air-aerated or sparged with helium to remove oxygen. Susceptibility also was independent of surface preparation. Pre-filming treatment in same fuel solution but without chloride added was 100% effective against cracking when chloride was added. Immunity to cracking was obtained whether specimens were pre-filmed before or after stressing. Bromide and iodide ions did not produce cracking.

**24 Review and Current Status of Bacterial Corrosion** by R. L. Starkey, Rutgers University, New Brunswick, N. J.

Discusses micro-organisms as having corrosive effects on many metals, in particular steel and cast iron, but they do not act directly on the metals. Their corrosive effects are brought about by substances they produce during growth on the organic or inorganic compounds of their environments. These products react directly with the metal. Micro-organisms also can become corrosive under aerobic and anaerobic conditions and in soil, water and industrial plants.

**25 Interference Aspects of Forced Drainage Installations Designed to Mitigate Corrosion of Underground Cables or Pipes** by S. C. Miller, Chesapeake and Potomac Telephone Company of Maryland, Baltimore, Md.

Presents general principals applicable to engineering design and installation of forced drainage systems (sometimes called cathodic protection systems) to protect wire line communication plant from noise induction and other types of interference that result from operation of such systems under certain conditions. Mechanics and control of noise induction into the telephone plant are discussed with earth potential effects and precautions to be observed.

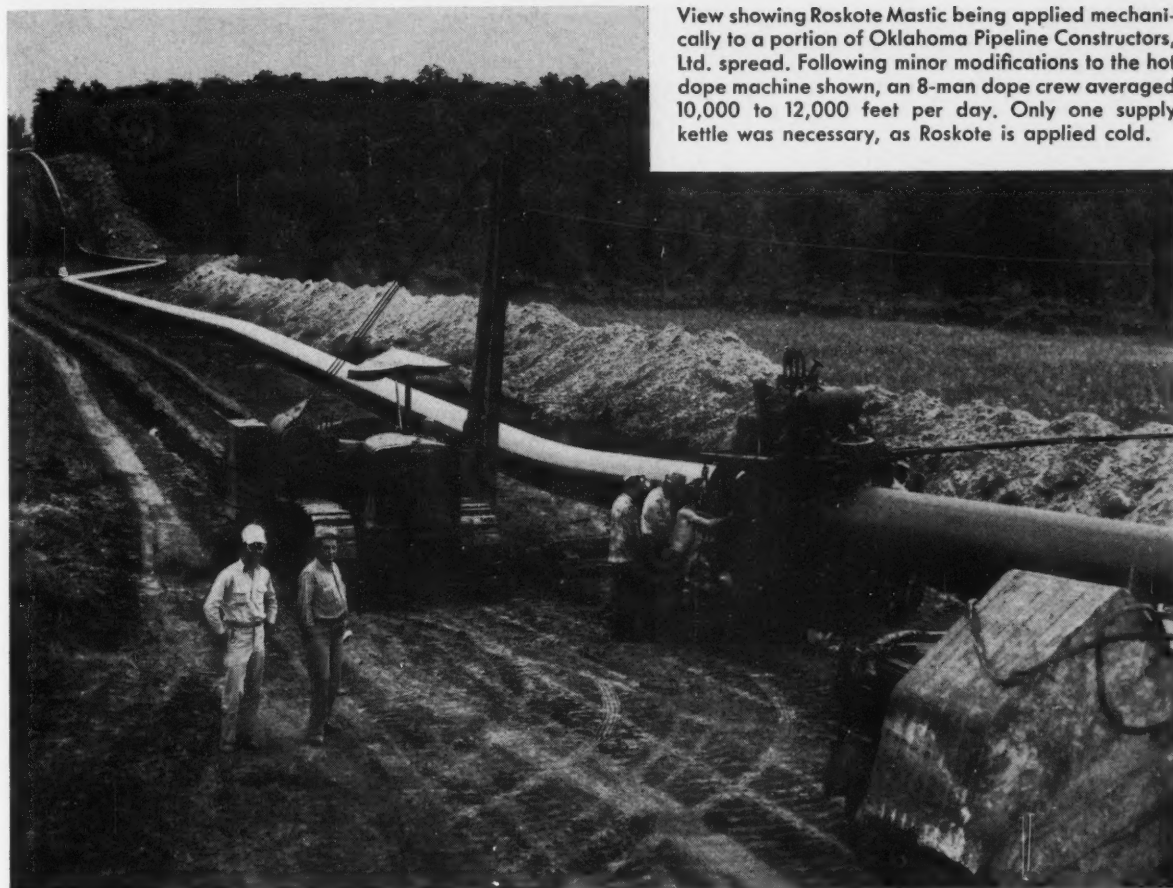
**26 Application of Corrosion Inhibitors in the Steel Industry** by E. H. Phelps, U. S. Steel Corp., Monroeville, Pa.

Discusses present applications of corrosion inhibitors in steel industry including use in slushing oils to prevent staining of sheet steel during storage and to prevent corrosion during pickling. Current research is given to emphasize need for improved inhibitors. Also discusses new applications including use of vapor-phase inhibitors for steel packaging.

**27 Inhibitors for Phosphoric Acid** by A. O. Fisher, Mansanto Chemical Co., St. Louis, Mo.

Presents procedures for laboratory screening and follow-up field evaluation of mineral acid inhibitors. Corrosion rates of steel and other metals in phosphoric acid under various conditions are given. Also discusses cost comparisons and other criterion to be considered in the commercial development of an inhibitor.

(Continued on Page 80)



View showing Roskote Mastic being applied mechanically to a portion of Oklahoma Pipeline Constructors, Ltd. spread. Following minor modifications to the hot dope machine shown, an 8-man dope crew averaged 10,000 to 12,000 feet per day. Only one supply kettle was necessary, as Roskote is applied cold.

## Roskote Applied Cold with Line Travel Equipment on Trans-Canada 30 Inch

Over rough terrain, with a right of way that crossed solid granite, muskeg, swamp and glacial till, and working under adverse weather conditions, the world's longest and most difficult pipeline construction — Trans-Canada Pipe Lines, Ltd. — has been completed.

One contributing factor in the success of this construction was the adaptation of standard line travel dope machines for the easy application of Roskote cold

mastic. This combination of Roskote Mastic and modified line travel machines made possible the coating of ten to twelve thousand feet per day of 30-inch piping on the downstream side of the compressor stations.

Contractors\* were able to carry on the coating operation with an 8-man dope crew, using only one supply kettle, requiring no heating fuel and thereby eliminating toxic fumes and fire hazard.

\*Contractors on Trans-Canada who applied Roskote by line travel equipment:

Morrison-Shivers, Ltd., Majestic Contractors, Ltd.,  
B. C. Rivers Construction, Ltd., Dutton-Williams Brothers, Ltd.  
and Oklahoma Pipeline Constructors, Ltd.

**ROYSTON LABORATORIES, Inc.**  
Blawnox, Pittsburgh 38, Pa.

**A LEADER IN THE FIELD OF INDUSTRIAL  
COATINGS FOR CORROSION CONTROL**

ATLANTA • CHICAGO • HOUSTON  
PHILADELPHIA • SAN DIEGO • TULSA



**ROYSTON LABORATORIES, Inc.**  
Pittsburgh 38, Pa.

C-8

Please send me complete information about the economics and application of cold-applied Roskote Mastic with line travel equipment.

Name

Company

Address

City  Zone  State



## Northeast Region Conference TECHNICAL PROGRAM

(Continued From Page 78)

**28** Researches on Corrosion and Inhibitors: Reaction Velocity in the Corrosion of Iron by Aqueous Hydrogen Sulfide and the Effect of Inhibitors by G. S. Gardner, Amchem Products, Inc., Ambler, Pa. Corrosion rate of iron was measured in sodium chloride brine containing 1000 to 2000 ppm of hydrogen sulfide  $H_2S$  in the presence and absence of an oil phase, in the absence of added inhibitor and was expressed by a previously developed rate equation. Results show inhibitor addition brings about a profound change in the reaction mechanism, efficient inhibitors changing the reaction from apparent first order diffusional type to a zero reaction.

**29** Some Reflections on the Automotive Applications of Corrosion Inhibitors by L. C. Rowe, General Motors Corp., Warren, Michigan. Discusses a few laboratory and service experiences in the use of inhibitors for temporary parts protection, engine coolants, gasolines, metal surface treatments and coatings and de-icing salts. Use of inhibitors for de-icing salts is reviewed in relation to degree of protection provided.

**30** Cathodic Protection of Steel-Hydrogen Embrittlement Studies by W. H. Bruckner, University of Illinois, Urbana, and K. M. Myles, Argonne National Laboratory, Urbana, Ill. Cathodically protected sections of hot rolled 2-inch steel pipe were subjected to low temperature bend tests. For M (N-80) steel, cathodic protection for 10 months under conditions of high tensile stress and excessive protection gave no indication of static failure or loss of strength and ductility in destructive tests upon removal from cathodic protection. Other steels tested were API grades A and B.

**31** Properties and Applications of Platinum Coated Anodes by C. E. Tirrell, Ionics Incorporated, Cambridge, Mass. Discusses use of platinum coated anodes in electrodialysis under operating conditions from 10 to 30 amperes per square foot with electrolyte concentrations from 3000 ppm brackish water to 36,000 ppm sea water.

**32** Preparation and Properties of a Stable Silver-Silver Chloride Electrode for Use in Sea Water by M. H. Ortner, Vitro Laboratories, West Orange, N. J. Discusses research of eight basic types of reversible electrodes surveyed with reference to their probable behavior in sea water. Estimates were made of the bias potentials expected between a group of electrodes in sea water due to thermal and salinity gradients, concentration polarization, attack by bromide ions and motion through the earth's magnetic field. Describes method of preparing the electrodes and the effect of their properties on behavior in sea water.

**33** Design Problems in Applying Permanent Cathodic Protection to Glass Lined Water Heaters by H. C. Fischer, Thermo-Craft Corp., Montville, N. J.

Investigation results on electrical resistances of production glass linings of domestic water heater tanks are presented with the conclusion that single coated enameled tanks have 0.02 to 0.09 square centimeters per square foot of holidays. A method using a saturated calomel reference cell to determine if all tank parts are protected is described and results on several tanks plotted.

Difficulties in cathodically protecting inlet and outlet fittings are discussed. A method is shown for correcting plastic liner difficulties and before and after voltage profiles are plotted.

An economical platinum clad tantalum anode is described. Use of high voltage plus use of high external resistance is shown to provide relatively constant current regardless of water conductivity. A 5-milliamperes current is shown to be effective in protecting good quality glass lined tanks.

**34** The Pentagon Story of Cathodic Protection by L. A. Major, Chesapeake and Potomac Telephone Company of Maryland, Baltimore, Md. Reviews early history of lead sheath cable failures and the control measures taken to alleviate troubles. Configuration of the several underground structures, water, power and communication is discussed with the effects of reduction current from temporary test anode beds. Includes a description of a cathodic protection system using several high silicon iron duct anodes and four high silicon iron deep anodes placed at bedrock.

**35** Corrosion of a Single Crystal of Aluminum by T. H. Orem, National Bureau of Standards, Washington, D. C.

Work on single crystals of aluminum revealed that there is a radical difference in aluminum's behavior in acids and caustics, the behavior in both being very orderly. When the corrodent is aqua regia, the attack on aluminum is rapid in a direction normal to close-packed arrangement of atoms, but the attack is slowest in this particular direction when the corrodent is a 15% solution of NaOH. Differences between the attack rates in directions normal to various surface atomic arrangements are illustrated by changes in shape of spheres, discs and other geometrical shapes after exposure to various corrodents.

### Technical Topics to Be Included in Annual Index

Technical Topics will be included in CORROSION's annual index. The Topics also will be included in the alphabetical subject and author index.

Persons who customarily extract Technical Section pages from each issue for binding are reminded that the Technical Topics pages should be extracted also for a more complete reference to technical information published in CORROSION.

## Harco... Super Market for Cathodic Protection Equipment!

Here's a one-source method of ordering all cathodic protection materials and equipment. YOU benefit through immediate delivery... the writing of one order... the receiving of one shipment. YOU save through the expected economies of large purchases and simplified shipping.

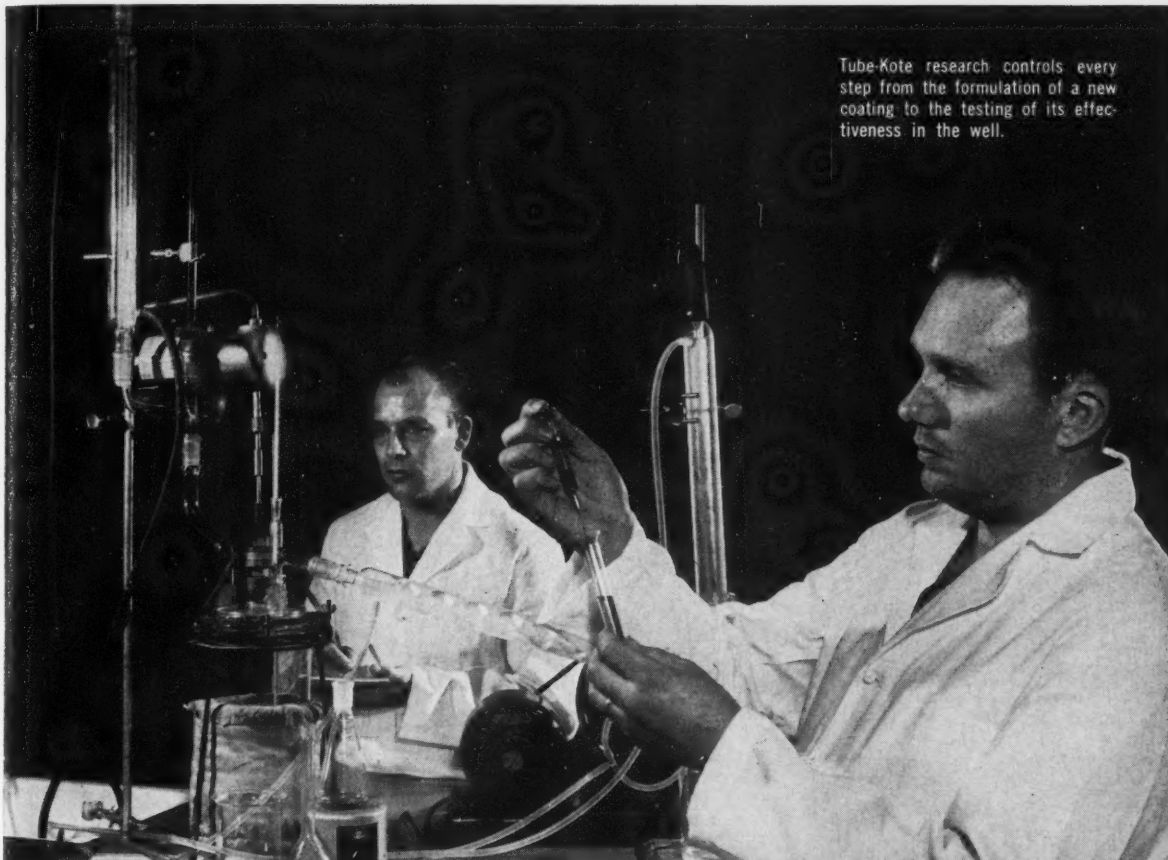
HARCO... first in the field of cathodic protection... stands ready to serve you NOW.



Cleveland • Atlanta •  
Chicago • Houston •  
Los Angeles • Minneapolis •  
New York • Oklahoma City •  
Pittsburgh • Salt Lake City •  
Seattle • St. Louis

<p>ANODES</p> <p>DOW-MAGNESIUM</p>	<p>ANODES</p> <p>NATIONAL CARBON • GRAPHITE</p>	<p>ANODES</p> <p>DURIION</p>
<p>RECTIFIERS</p> <p>HARCO</p>	<p>BRAZING EQUIPMENT</p> <p>CADWELD</p>	<p>TAPE</p> <p>POLYKEN</p>

**THE HARCO CORPORATION**  
4592 East 71st Street,  
Cleveland 25, Ohio  
VULcan 3-8787



Tube-Kote research controls every step from the formulation of a new coating to the testing of its effectiveness in the well.

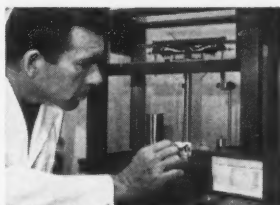
# TUBE-KOTE®

## *Why Coatings Are Consistently Superior In Quality*

Standardization of materials used in the Tube-Kote automatic coating process is vital to maintaining desired quality. Any variation of pigment, binder or solvent will change the thickness, flow and uniformity of the coating.

Tube-Kote researchers test all materials before they are used in the plants to make certain that they meet specified standards.

Tube-Kote employs a large, full-time research laboratory to maintain quality control . . . to develop new and improved coatings . . . to solve special coating problems for customers . . . to keep Tube-Kote foremost in the industry it created almost 20 years ago.



Quantitative and viscosity tests are run on every batch of coating to make sure that all components are in balance as prescribed in the original coating formulation.



Service Mark Reg. U. S. Pat. Off.

P. O. Box 20037 • Houston 25, Texas  
Branch Plant • Harvey, La.

TUBE-KOTE RESEARCH AND SUPERIOR METHODS BRING YOU MORE DURABLE COATINGS AND FASTER SERVICE . . . AT LOWER COST PER FOOT!

# Authors of Papers, 1959 Northeast Regional Conference



Atkinson



Basil



Birnbaum



Bloom



Breslau



Bruckner



Burnett



Capp



Cook



Copson



Cowling



Denhard



Devoluy



English



Ephraim



Fischer



Fisher



Flegenheimer



Francis



Fraser



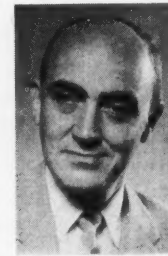
Gardner



Goodson



Greene



Griess



Guerry



Horst



Johnstone



Kemp



Knoedler



Lane

Why  
e  
t  
i  
I

Put aw  
of them  
Series V  
habit, t  
equal"  
responsi

Sure,  
order. B  
of Pruf  
applicat  
deterior

Why  
"A" Ser  
reasons,

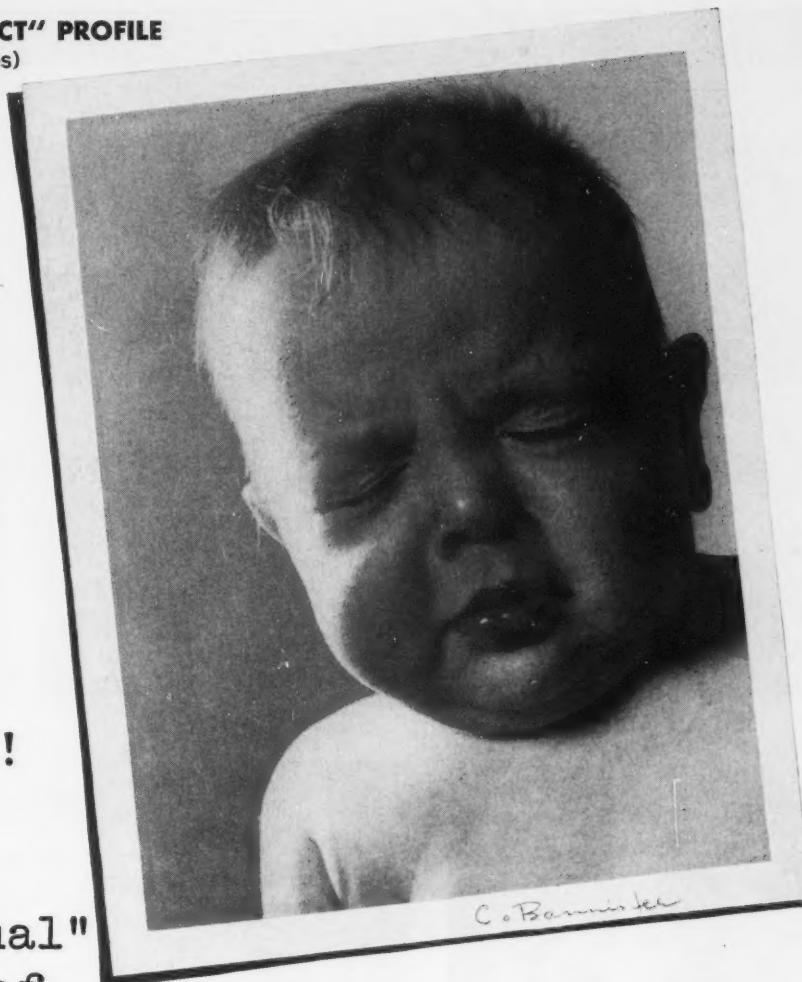
As a  
mainten  
the best  
ing form  
chemical  
quality  
convent

Main O



## A "PRUFCOAT PRODUCT" PROFILE

(one of a series)



Oh, brother!  
Why did I  
ever buy  
that "or equal"  
imitation of  
Prufcoat "A" Series Vinyl ?

Put away the crying towel, friend. It happens to the best of them. A specifications engineer decides on Prufcoat "A" Series Vinyl—spells everything out carefully—then, out of habit, tacks on that easy-to-write, but hard-to-prove, "or equal" bit. And later, the guy with on-the-job buying responsibility settles for an "or equal" imitation.

Sure, maybe he saves a few pennies on the purchase order. But he never gets to enjoy the money-saving benefits of Prufcoat Service—and he starts losing dollars fast once application problems crop up, once the coating starts to deteriorate, once corrosion gains the upper hand.

Why take chances? Top companies today specify Prufcoat "A" Series Vinyl—and stop right there. For compelling reasons, too.

As a general-purpose corrosion resistant coating for both maintenance and new construction, "A" Series offers you the best balance of properties to be found in a single coating formulation. You are assured of the high degree of chemical resistance you are entitled to expect from a top-quality vinyl coating. Ease of application rivals that of conventional oil paints. You brush or spray without thinning.

Yet, solids content is higher than the average general-purpose vinyl. You get essential minimum coating thickness in fewer coats.

Prufcoat "A" Series Vinyl bonds securely to any of the wide array of Prufcoat primers, sealers and undercoaters that accommodate just about every surface—and surface condition—you are likely to run up against. You are assured of trouble-free applications and years of low-cost service life.

# PRUFCOAT

PROTECTIVE COATINGS

### WHY NOT PUT PRUFCOAT PRODUCTS TO WORK FOR YOU?

Your Prufcoat service representative can show you how to put Prufcoat corrosion resistant primers and coatings to most effective, money-saving use. There is no cost or obligation. Just write or call ● ● ●

### PRUFCOAT LABORATORIES, INC.

Main Office & Plant: 63 Main St., Cambridge 42, Mass. • New York Sales Office: 50 East 42nd Street, New York 17, N. Y.

Warehouses: Atlanta—Buffalo—New Orleans—San Francisco—Seattle

# Authors of Papers, 1959 Northeast Regional Conference



Logan



Major



Morthens



Miller



Mullett



Myles



Naumann



Orem



Ortnier



Phelps



Philibert



Preiser



Pryor



Rosenbaum



Rowe



Starkey



Sturla



Suss



Tirrell



Tytell

## Northeast Region Conference BIOGRAPHIES

**P. W. ATKINSON** is a section head at Thiokol Chemical Corp., Trenton, N. J. He has a BS from Youngstown University and a MS from Ohio State University. He is a member of the Engineering Society of Detroit and the American Chemical Society's Rubber Division.

**J. L. BASIL** is a project engineer in the Metallurgy Department of the U. S. Naval Engineering Experiment Station, Annapolis, Md. He has specialized in marine corrosion work since 1946 and has been an NACE member since 1947. He has a BS in engineering science from St. John's College.

**L. S. BIRNBAUM** is head of the Hull Preservation, Decking and Insulation Section of the Bureau of Ships, Navy Department, Washington, D. C. He has a BS in chemistry from New York City College and is a graduate in chemistry from the University of Maryland. He is a member of NACE and the American Chemical Society.

**M. C. BLOOM**, consultant for the Metallurgy Division of the U. S. Naval Research Laboratory, Washington, D. C., has a BS in chemical engineering and a PhD in physical chemistry from MIT. He is a member of ACS, ASM, Crystallographic Association, Electrochemical Society, Electroplaters Society and NACE.

**H. R. BRESLAU** is vice president and general manager of Southern Galvanizing Co., Baltimore, Md. He has a degree in electrical engineering from Johns Hopkins University and is a member of the American Hot Dip Galvanizers Association, Maryland Association of Engineers and NACE.

**W. H. BRUCKNER** is professor of metallurgical engineering and technical director of the Cathodic Protection Laboratory at the University of Illinois. He has written papers on cathodic protection of lead cable sheath and has been active in research on metallurgy and welding problems.

**R. L. BURNETT**, a supervisory chemist at the Boston Naval Shipyard, has been active in development work for the cathodic protection of ship bottoms and in exploring the mechanism of cavitation damage of propellers and ship appendages. He is a graduate of Northeastern University and a member of NACE Technical Committee T-3G.

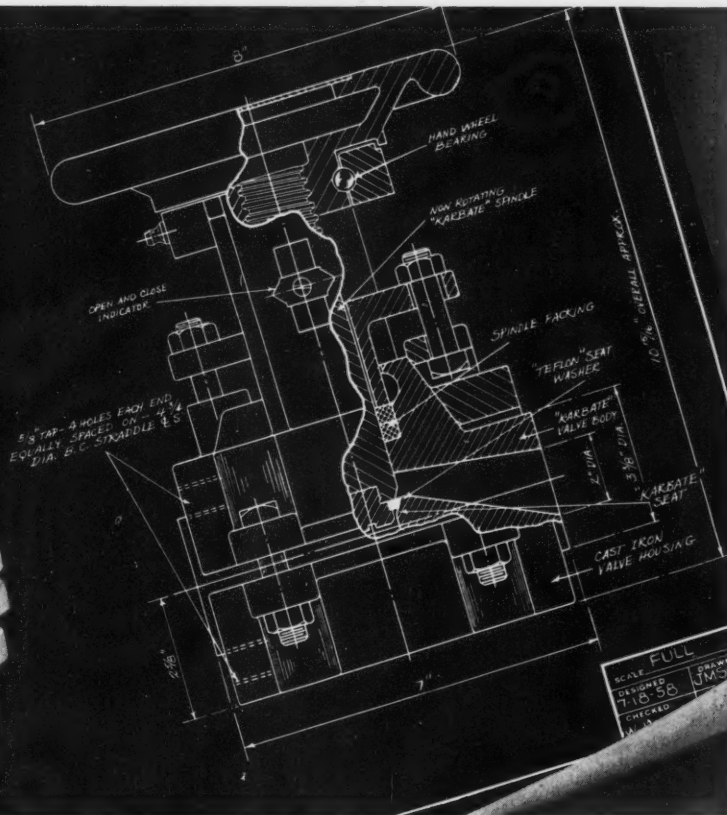
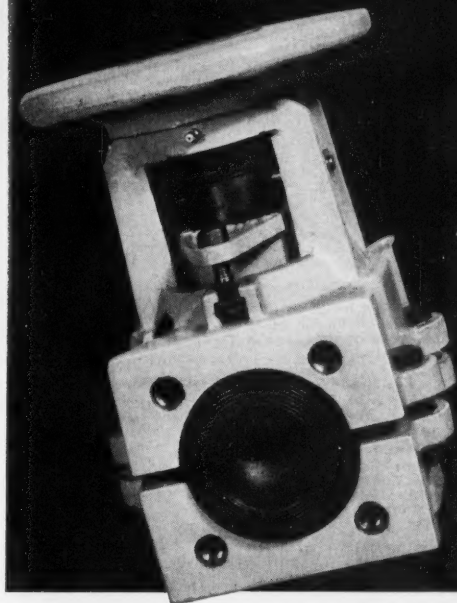
**R. S. CAPP**, a lieutenant commander in the Coast Guard, is chief of the Naval Engineering Section, Eighth Coast Guard District, New Orleans. He is a member of the Society of Naval Architects and Marine Engineers, American Society of Naval Engineers and an associate member of American Welding Society.

**F. E. COOK** is supervising materials engineer with the Navy Department's Bureau of Ships, Washington, D. C. He has a BS in chemistry from Roanoke College and a MS in chemical engineering from Ohio State University. He is a member of NACE, ACS and ASNE.

**H. R. COPSON** is head of the corrosion section of the Research Laboratory, International Nickel Co., Inc., Bayonne, N. J. He has a BS from the University of Massachusetts and a PhD in physical chemistry from Yale. He has been active in corrosion research since 1934.

(Continued on Page 86)

Announcing  
the  
**NEW...**



## "KARBATE" GLOBE VALVE TYPE G

National Carbon Company announces the availability of a completely new "Karbate" impervious graphite globe valve. The many new design features of this valve were performance tested for approximately 1 year prior to adoption.

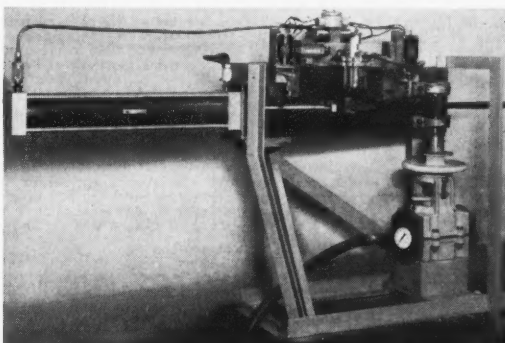


Photo shows test equipment for opening and closing valve to simulate years of actual plant operation. This set-up provided checks on the wearing qualities of spindle threads, sealing qualities of the "Teflon" plastic to carbon seat, and the leak-proof operation of spindle packings.

### Principal design features:

- "Teflon" plastic to carbon seat—provides positive seal when valve is closed.
- Metal handwheel to "Karbate" spindle thread design—provides long operational life—no binding because of corrosion.
- Non-rotating spindle—simplifies spindle packing problem. Provides leak-tight seal using a variety of packings such as asbestos impregnated with "Teflon" plastic, braided "Teflon" plastic, asbestos impregnated with graphite and elastomers.
- Lubricated ball-bearing handwheel to yoke arrangement—provides easy movement of handwheel with positive lock to yoke.
- Armored design—prevents outside shock damage.
- Positive indication of open and closed positions.
- Valve can be adapted to motor operation.
- Almost universal corrosion resistance—can be used in a wide variety of corrosive chemicals. All wetted parts are "Karbate" impervious graphite or "Teflon" plastic.

Presently, this valve is available in the two inch size. One inch, one and one-half inch, three inch and four inch valves will be added to the line in the future.

"National", "Karbate" and "Union Carbide" are registered trade-marks of Union Carbide Corporation

**NATIONAL CARBON COMPANY • Division of Union Carbide Corporation • 30 East 42nd Street, New York 17, N.Y.**

**SALES OFFICES:** Atlanta, Chicago, Dallas, Kansas City, Los Angeles, New York, Pittsburgh, San Francisco • **IN CANADA:** Union Carbide Canada Limited, Toronto





## Northeast Region Conference BIOGRAPHIES

(Continued From Page 84)

**J. E. COWLING** is in charge of the organic coatings section of the Organic and Biological Chemistry Branch of the U. S. Naval Research Laboratory. He has a BS in chemical engineering from Virginia Polytechnic Institute and is a member of NACE, ACS and Society of American Military Engineers.

**E. E. DENHARD, JR.**, is senior research engineer with Armco Steel Corp., Baltimore, Md. He has a BS from Purdue University and MS from Johns Hopkins University. He is a member of ASM and Maryland Institute of Metals.

**R. P. DEVOLUY** is marine manager of Glidden Company, New York, N. Y. He has a BS and MS in chemical engineering, has written technical papers on coatings and marine corrosion and is a member of NACE, ACS and Society of Naval Architects and Marine Engineers.

**J. L. ENGLISH** is a group leader in the Solution Materials Corrosion Section at Oak Ridge National Laboratory. He has a BS in chemical engineering from Syracuse University, has written technical reports on corrosion of aluminum and its alloys in aqueous systems and is a member of NACE, RESA and ASM.

**S. N. EPHRAIM** is head of polyurethane and epoxy resin research and development at Reichhold Chemical Corp., Elizabeth, N. J. He has a BS in chemistry from the University of Michigan and a MS from Polytechnic Institute of Brooklyn. He is a member of ACS, SPI and ASTM.

**H. C. FISCHER** is vice president of Thermo-Craft Corp., Montville, N. J. Formerly he was associated with Temprite Products Co., Detroit, and Ebco Mfg. Co., Columbus, Ohio. He has a BS in chemical engineering and a MS in metallurgical engineering from the University of Michigan and is a member of NACE and chairman of Technical Committee T-4E.

**A. O. FISHER** is corrosion consultant and laboratory supervisor in Monsanto Chemical Company's corporate corrosion group at St. Louis, Mo. He has a BS in chemical engineering from Northeastern University and has been associated with Monsanto since 1944. He is a member of NACE, ASM and ACS.

**H. H. FLEGENHEIMER**, technical director with eastern industrial and marine divisions of Devoe & Reynolds Co., Inc., has a BS in chemical engineering from the Cooper Union School of Engineering and a MS from the Polytechnic Institute of Brooklyn. He is a member of NACE, ACS and the New York Paint and Varnish Production Club.

**R. C. FRANCIS** is a general engineer with the Navy Department's Bureau of Ships, Washington, D. C. He has a BS in chemistry from Bridgewater College and is a member of NACE.

**W. A. FRASER** is a physical chemist with the Naval Research Laboratory, Washington, D. C. Author of corrosion studies in high temperature water by a hydrogen effusion method, he has a BS from Ohio University and is a member of ACS.

**G. S. GARDNER**, research chemist with Amchem Products Inc., has written several technical papers and holds patents on several corrosion inhibitors. He is a member of NACE, Franklin Institute, API, AAAS, ACS and American Institute of Chemists.

**J. B. GOODSON, JR.**, is senior engineer with Sheppard T. Powell and Associates, Baltimore, Md. He has a BS from the University of Florida and served as a lieutenant colonel in the U. S. Army Chemical Warfare Service during World War II.

**N. D. GREENE** is research metallurgist with Union Carbide Metals Co., Niagara Falls, N. Y. Author of several technical papers published in CORROSION, he has a BS in chemical engineering from the University of Rochester and a MS and PhD in metallurgy from Ohio State University. He is a member of NACE, ASM, Electrochemical Society and the Welding Research Council.

**J. C. GRIESS** has been engaged in corrosion testing and reactor chemistry at Oak Ridge National Laboratory since 1950. He has a BS and MA in chemistry from Indiana University and is a member of NACE, ACS and the Electrochemical Society.

**W. A. GUERRY** is marine manager of Amercoat Corp., Kennilworth, N. J. He is a graduate of Union College and is a member of NACE and the Society of Naval Architects and Marine Engineers.

**R. L. HORST, JR.**, is affiliated with the sales development division of Aluminum Company of America. His work is on aluminum applications in the chemical and process industries. An NACE member and a graduate of Columbia University, he has published several articles on aluminum and cathodic protection by aluminum and magnesium anodes.

**J. W. JOHNSTONE, JR.**, is supervisor of the engineering research electrical section, Engineering and Construction Department, Atlantic Refining Co., Philadelphia, Pa. Formerly an electrical engineer with Day & Zimmermann, Inc., he is a graduate of Cornell University and a member of AIEE.

**W. E. KEMP** is coatings section technical director of Koppers Company, Inc., Tar Products Division. A graduate of the University of Toronto, he holds several patents in organic chemistry and coatings and is a member of the Sea Horse Institute, NACE, Chemical Society, ACS and ASAS.

**E. L. KNOEDLER**, affiliated with Sheppard T. Powell and Associates, Baltimore, Md., has a ME in mechanical engineering from Cornell University and a MS and PhD in chemical engineering from Columbia University. He is a member of ASME, AIChE, ACS and AWWA.

**J. J. LANE** is technical representative of the coating section, Product Development Department of Koppers Co., Inc. He is a graduate of the University of Pittsburgh and has been active in the field of emulsion coatings for several years.

**H. L. LOGAN**, associated with the National Bureau of Standards since 1936, has a BS in chemistry from Tarkio College and a MS in physics from the University of Colorado. He is a member of NACE, ASM, Electrochemical Society and Washington Academy of Sciences.

**L. A. MAJOR** is a plant engineer with Chesapeake & Potomac Telephone Co. His work is in corrosion control for the company's Washington metropolitan area. He has been an NACE member since 1951.

**A. S. MARTHENS** is mathematical statistician in charge of quality control with the U. S. Navy Department. He has a BS in electrical engineering from Carnegie Institute of Technology and is a member of AIEE, IRE, IMS, ASA and ASQC.

**S. C. MILLER** has been associated with the general engineering department of Chesapeake and Potomac Telephone Company of Maryland since 1928. He has a BS in electrical engineering from Virginia Polytechnic Institute and is a member of AIEE.

**T. A. MULLETT** is an engineering supervisor with Atlantic Refining Co., Philadelphia, Pa. He has a BS in mechanical engineering from Purdue University and is a member of API and ASME. He has been active in committee work dealing with corrosion and protective coatings problems.

**K. M. MYLES** is a metallurgical engineer at Argonne National Laboratory, Lemont, Ill., where he is engaged in research on fundamental mechanisms of radiation damage to metals. He has a BS and MS from the University of Illinois.

**W. C. NAUMANN** is group leader of the Surface Coatings Resin Section at Union Technical Service Laboratory. He has a BS in chemistry from Seton Hall University and a MS in chemical engineering from Newark College of Engineering.

**T. H. OREM**, a metallurgist with the National Bureau of Standards, Washington, D. C. has a BS in metallurgical engineering from Michigan College of Mining and Technology. He has written several papers on corrosion and is a member of ASM.

**M. H. ORTNER**, project leader with Vitro Laboratories, has a BS in chemistry from City College of New York and a MS in chemistry from the University of Delaware. Formerly he was associated with Allied Chemical and Dye Corp., and the Du Pont Co.

**E. H. PHELPS** is an assistant division chief of U. S. Steel Corporation's Applied Research Laboratory at Monroeville, Pa. He has a BS in chemical engineering from Clarkson College of Technology and a MS and PhD from Case Institute of Technology. He is a member of NACE and the Electrochemical Society.

**B. J. PHILIBERT** is associated with Pittsburgh Coke & Chemical Co., Protective Coatings Division. Formerly he was with Olin Mathieson Chemical Corporation in charge of corrosion service and standards development. He is a past chairman of the NACE Baltimore-Washington Section.

**H. S. PREISER**, corrosion engineer with the Navy Department's Bureau of Ships, Washington, D. C., is a graduate of New York State Maritime College and Webb Institute of Naval Architecture. He is chairman of the Technical Program Committee for the 1959 Northeast Region Conference.

**M. J. PRYOR** is chief of the chemical and physical section of the Olin Mathieson Chemical Corp. He is a graduate of Cambridge University, England, with a BA, MA and PhD in chemistry. He has written 25 papers on corrosion research and is a member of NACE, Electrochemical Society and Society of Naval Architects and Marine Engineers.

**B. B. ROSENBAUM** is technical administrator of the Navy Department Bureau of Ships' programs on high temperature metallurgy and semiconductors for thermo-electric power conversion and Peltier heat pumping. He is a metallurgical engineering graduate of the University of Pittsburgh.

**L. C. ROWE** is a senior research chemist with General Motors Corp., Warren, Michigan. He has a BS and MS from Michigan State University and is a member of NACE and ACS. He has published several technical articles in CORROSION.

**R. L. STARKEY**, professor and research specialist in agricultural microbiology at Rutgers University, holds several patents on measurement of corrosive characteristics of soil and has written technical papers in this field. He has a BS from Massachusetts Agricultural College and a MS and PhD from Rutgers College.

**PIERO STURLA** is chief of the central laboratory at Edisonvolta in Milano, Italy. A graduate of the Universities of Genoa and Parma, he has been working in the fields of boiler feed water conditioning and other boiler water corrosion problems.

**HENRY SUSS** is a material engineer at General Electric's Knolls Atomic Power Laboratory, Schenectady, N. Y. He has a BS from New York University and a MA from Columbia University. He has been in corrosion work for 12 years.

**C. E. TIRRELL**, senior chemist with Ionics, Inc., is a graduate of Boston University and has been engaged in research and development of electrodialysis processes and equipment. He has been with Ionics, Inc., since 1949.

**B. H. TYTELL**, research chemist at the Boston Naval Shipyard, has been in marine corrosion work since 1930. He has a BS in chemistry from Brooklyn Polytechnic Institute and is a member of NACE, Electrochemical Society and Society of Plastics Engineers.

Southern

10 C

Are

Tech

Ten to the 1959 program Meyer

Subject rigid plan maintenance

NACE Aluminum Ontario, reference "You."

General program tion Pi Georgia. is Arthur

Abstract presented are given



Jeff

Southern

A B

Corrosion Pulp Mill Alloy Steel Presents corrosion for equipment describes plant case history sulfite, sulfurous systems the bleaching is given of various products

Rigid Plastic Corp., S Discusses plastics in saturation industry for light weight physical and of various pipe.

Biological Environment Clapp L General summary of marine environment the deterioration

Salt Water American Describes during first Coast refinery water and equipment deposits in

# Southeast Region Conference Opens October 1

## 10 Corrosion Papers Are Scheduled for Technical Program

Ten technical papers are scheduled for the 1959 Southeast Region Conference program, October 1-2, at the Robert Meyer Hotel, Jacksonville, Florida.

Subjects cover a broad scope from rigid plastic pipe to the economies of maintenance painting.

NACE President Hugh A. Godard, Aluminum Laboratories, Ltd., Kingston, Ontario, Canada, will speak to the conference on "What NACE Can Do For You."

General chairman for the conference program is George M. Jeffares, Plantation Pipe Line Company, Atlanta, Georgia. Local arrangements chairman is Arthur B. Smith, Amercoat Corp.

Abstracts of technical papers to be presented during the 2-day conference are given below.



Jeffares



Smith

## Southeast Region Conference ABSTRACTS

**Corrosion of Stainless Steels and Higher Alloys in Pulp Mill Operations**, by H. C. Templeton, Alloy Steel Products Co., Linden, N. J. Presents consideration of limiting corrosion rates for equipment with low corrosion tolerance. Describes plant corrosion test rods. Also presents case histories in various pulping processes covering sulfite, sulfate, alkaline, semi-chemical and continuous systems. Corrosion problems associated with the bleaching operation are covered also. Summary is given of the most commonly used materials for various processes.

**Rigid Plastic Pipe**, by W. R. Dana, Amercoat Corp., South Gate, Cal. Discusses properties of glass fiber reinforced plastics in satisfying needs and requirements of industry for high strength, corrosion resistant and light weight piping. Discusses design, manufacture, physical and chemical properties and applications of various types of glass fiber reinforced plastic pipe.

**Biological Deterioration of Materials in Marine Environments**, by A. P. Richards, William F. Clapp Laboratories, Inc., Duxbury, Mass. General survey of the marine organisms contributing to deterioration of structural materials in marine environments, the mechanics and extent of the deterioration and preventive methods.

**Salt Water Corrosion in Refineries**, by P. J. Hurd, American Oil Co., Yorktown, Va. Describes some corrosion problems encountered during first two years of operation at an East Coast refinery. These include experiences with sea water and conventional piping and heat exchange equipment and the effect of chloride and sulfide deposits in reforming equipment.

**The Corrosion Program—Where Management Fails**, by S. W. Walker, East Tennessee Natural Gas Co.

Explains the failure of management to place the corrosion program on the same level as other industrial programs. Weaknesses of the present procedure are compared to advantages of a stronger corrosion program.

**Mill Scale as a Base for Protective Coatings**, by Kenneth Tator, Kenneth Tator Associates, Coraopolis, Pa.

Describes a study of coating performances over mill scale bearing steel involving several thousand performance evaluations of coating performances in about 100 different industrial exposures using different coating systems of industrially useful coating types. Conclusions and recommendations based on the study are given.

**Corrosion Resistance of Aluminum in Marine and Industrial Atmosphere**, by R. L. Horst, Aluminum Company of America, New Kensington, Pa. Test data and service experience are combined to present an over-all picture of aluminum applications in corrosive atmospheres. Special attention given to the paper industry.

**Corrosion Mitigation on 6 Gas Distribution Systems in Florida**, by J. S. Frink, Houston Corp., Miami, Fla.

Corrosion and leakage control program planned for 6 gas distribution systems includes existing systems and planned expansions in Miami, Orlando, Lakeland, Mount Dora, Eustis, Umatilla, Winter Park, Maitland, Daytona Beach and Jacksonville.

**New Developments on Cathodic Protection Rectifiers**, by T. R. Stilley, Good-All Electric Mfg. Co., Ogallala, Neb.

**A Modern Approach to Planning a Maintenance Coating Program**, by M. W. Belue, Jr., Champion Paper & Fibre Co., Pasadena, Texas. Gives details of a plan to solve corrosion problems through a coatings program. Various phases of the program are discussed: cost, personnel, time and service life expected. Accomplishments of the program over a 4-year period are evaluated.

## Southeast Region Conference BIOGRAPHIES

**M. W. BELUE, JR.**, is protective coating consultant at the Texas division of Champion Paper & Fibre Co., Pasadena, Texas. A graduate of Duke University, formerly he was president of a firm which he organized handling sales and special application of corrosion preventive materials.

**W. R. DANA** is chief engineer of Amercoat Corp., South Gate, Cal., and is responsible for the company's engineering and plant management of the reinforced plastics pipe operations. Formerly he was design engineer with American Pipe and Construction Co. He has a BS in engineering from Stanford University.

**J. S. FRINK** is an engineer with the Houston Corp., St. Petersburg, Fla. A member of NACE since 1945, he is vice chairman and charter member of the South Florida Corrosion Control Committee, immediate past chairman of the Southeast Region and has written papers and articles in the gas industry and corrosion engineering fields.

**R. L. HORST, JR.**, is affiliated with the sales development division of Aluminum Company of America. An NACE member and a graduate of Columbia University, he has published several articles on aluminum and cathodic protection by aluminum and magnesium anodes.

**P. J. HURD** is chief plant engineer of American Oil Company's refinery at Yorktown, Va. He has a BS in mechanical engineering from Texas A & M College.

**A. P. RICHARDS** is president and director of the William F. Clapp Laboratories, Inc., Duxbury, Mass. He has a BS from the University of Massachusetts and joined the Clapp Laboratory staff in 1937.

**T. R. STILLEY** is field service manager for the electrical-mechanical division of Good-All Electric Mfg. Co., Ogallala, Neb. He has a BEE from Marquette University. Formerly, he was associated with Shell Oil Co., and Illinois Power Co. He is a member of AIEE, AGA and NACE. He is co-author of the Corrosion Manual for the Illinois Power Company.

**KENNETH TATOR** is head of Kenneth Tator Associates, paint consultants in Coraopolis, Pa. He has had 30 years of experience in the coatings field and has been a member of NACE since 1945. He has written several articles and papers on coatings and holds patents on container linings, plastics products and corrosion barriers.

## Southeast Region Conference AUTHORS



Belue



Dana



Frink



Horst



Hurd



Stilley



Tator



Templeton

**H. C. TEMPLETON** is chief metallurgist for Alloy Steel Products Co., Linden, N. J. His work is in production, application and corrosive service performance of stainless steel castings and valves constructed from stainless steel castings. He is active in NACE and ASTM activities.

Over 20,000 cards have been issued by the NACE Abstract Punch Card Service.

# Western Region Conference Begins Sept. 29

## General Corrosion Problems to Be Covered in Program

The 9th Annual Western Region Conference will be held Sept. 29-Oct. 1 at the Bakersfield Inn, Bakersfield, Cal. Seven symposia and one open forum on general corrosion problems have been scheduled in which technical papers on various aspects of corrosion will be presented.

A fellowship hour and banquet will be held Wednesday, Sept. 30. Ladies are invited to the banquet.

Conference chairmen are as follows: R. M. Evans, Standard Oil Company of California, general chairman; J. W. Wilt, Honolulu Oil Corp., program chairman; A. J. Nierman, Standard Oil of California, publicity chairman; C. J. Smith, Western Gulf Oil Co., facilities chairman; E. A. LeDuc, Dearborn Chemical Co., hospitality chairman; J. Penner, Magna Products, Inc., registration chairman; J. A. Bessom, Richfield Oil Corp., membership chairman; J. P. Mitchell, Jones & Keller, Inc., ladies activities chairman.

Conference program is as follows:

### Tuesday, Sept. 29

#### 8:30 AM

Conference registration: \$20 per person, fee including fellowship hour and banquet. Additional banquet tickets \$5 each.

#### Conference Opening

Welcome address by Conference Chairman R. M. Evans, Standard Oil Company of Cal.

Welcome to Bakersfield by Mayor Frank Sullivan

Introduction to keynote address by R. I. Stark, Chairman, Western Region

Luncheon (\$2 per person)

Speaker: Fred Wilkes, Dearborn Chemical Co.

Subject: Atomic Reactors

#### PM

#### General Corrosion Symposium

E. A. LeDuc, Dearborn Chemical Co., chairman

Isophthalic Resins for Corrosion Control and Maintenance, by G. B. Johnson, California Research Corp.

(Two papers to be added)

#### Chemical Processing Symposium

H. F. Keller, Jr., Jones & Keller, Inc., chairman

Use of Stainless Steels in the Chemical Process Industry, by E. G. Holmberg, International Nickel Co.

Precision Coatings for Corrosion Control, by B. E. Martin, Ferro-Martin Company.

Preventive Corrosion Control in Engineering Design, by I. C. Bechtold, consulting engineer.

### Wednesday, Sept. 30

#### AM

Registration: Bakersfield Inn

#### Petroleum Producing Symposium

B. A. Grover, Western Gulf Oil Co., chairman

Cathodic Protection Applied to Internal Surfaces of Vessels, by R. L. Davis, Superior Oil Co.

Analysis of Oil Field Corrosion Problems, by J. F. Chittum, California Research Corp.

Field Problems Encountered With Oil Field Scale and Corrosion, by E. G. Kozlowski, Jones & Keller, Inc.

#### Utilities Symposium

R. O. Dean, Pacific Gas & Electric Co., chairman

Corrosion Control in Water Treatment Plants, by F. O. Waters, San Diego Utilities Department.

Cathodic Protection Coordination Methods and Practices, by D. T. Jones, Pacific Telephone and Telegraph Co.

A Miscellany of Mitigated Corrosion Problems of a Public Utility, by H. A. Medlock and H. H. de Laneux, Pacific Gas and Electric Co.

#### PM

#### Petroleum Producing Symposium (cont'd)

B. A. Grover, Western Gulf Oil Co., chairman

Microbiology in Secondary Recovery Systems, by L. L. Wolfson, Nalco Chemical Co.

Cathodic Protection of Oil Well Casing: a panel discussion.

Aluminum Applications in the Petroleum Industry, by E. T. Wanderer, Aluminum Company of America.

#### Pipelines Symposium

J. A. Bessom, Richfield Oil Corp., chairman

Cathodic Protection Fundamentals

Groundbed Development

Practical Solutions to Cathodic Interference Problems, by J. W. Ritter, Southern California Gas Co.

#### 6:30 PM

Fellowship Hour

#### 8 PM

Western Region Conference Banquet.

Speaker: Robert R. Gros, vice president, Pacific Gas and Electric Co.

### Thursday, Oct. 1

#### AM

#### Petroleum Processing Symposium

J. B. Armstrong, Standard Oil Company of California, chairman

Correlation of Corrosion in a Crude Distillation Unit With the Chemistry of the Crude, by R. L. Piehl, Standard Oil Company of California.

Corrosometer Plus Statistical Analysis Yield Unique Approach to Corrosion Problems, by J. T. Patrick and G. E. Moller, Union Oil Company of California.

Selection of Materials for Refinery Corrosion Prevention, by A. P. Maradudin, Standard Oil Company of California.

#### Marine Symposium

P. W. Hill, Signal Oil & Gas Co., chairman

Corrosion of Internal Surfaces of Tankers

Cathodic Protection of Ship Hulls

Cathodic Protection of Offshore Drilling Platforms

#### PM

#### Petroleum Processing Symposium (cont'd)

Centralized Chemical Feed to Multiple Cooling Tower Systems, by W. B. Harrison, Tidewater Oil Co., and P. G. Bird, Wright Chemical Corp.

(Two papers to be added)

#### Open Forum on Corrosion Problems

H. J. Keeling, consulting engineer, moderator

(Subjects and speakers to be scheduled)

## Western Region Conference ABSTRACTS

### Chemical Processing Symposium

Use of Stainless Steels in the Chemical Process Industry, by E. G. Holmberg, International Nickel Co., Inc., New York, N. Y.

Discusses behavior of wrought and cast austenitic stainless steels when exposed to various environments at room and elevated temperatures. Also presents the effect of variations in composition and microstructure on corrosion resistance.

Precision Coatings for Corrosion Control, by B. E. Martin, Ferro-Martin Company.

Gives some reasons for precision control in preparation of surfaces and formulations. Discusses new products and application techniques and results which can be expected from them.

Preventive Corrosion Control in Engineering Design, by I. C. Bechtold, consulting engineer.

Several major sources of corrosion which are aggravated by lack of attention to basic principles involved in corrosion effects are described and discussed. Practical problems are given of correlating corrosion prevention with chemical engineering design by engineers uninitiated in the field of corrosion. Set of corrosion check sheets are presented with suggested use in connection with design of each piece of equipment.

### General Corrosion Symposium

Isophthalic Resins for Corrosion Control and Maintenance, by G. B. Johnson, California Research Corporation.

Gives preliminary report on use of isophthalic polyesters for corrosion control and general maintenance. These new resins have been used as clear coatings to protect clean metal surfaces, in construction of glass fiber reinforced laminated tank bottoms to 115 feet in diameter and in combination with inorganic fillers as patching putty for repairing small leaks in pipelines and vessels.

### Petroleum Processing Symposium

Corrosometer Plus Statistical Analysis Yield Unique Approach to Corrosion Problems, by J. T. Patrick and G. E. Moller, Union Oil Company of California, Rodeo, Cal.

Describes new technique for analyzing corrosion data. A Type 501 probe installation in a refinery thermal cracking unit provided such reliable corrosion data that corrosion rates could be correlated with certain process variables by the statistical method of regression analysis. An electronic digital computer was used to process data and correlate significant variables. Procedure permits corrosion to be predicted on a day-to-day basis, an advantage when corrosion rates within an operating plant fluctuate because of feed stock changes and process control changes.

Centralized Chemical Feed to Multiple Cooling Tower Systems, by W. B. Harrison, Tidewater Oil Company, Ventura, Cal., and P. G. Bird, Wright Chemical Corp., Chicago, Ill.

Describes feeding corrosion inhibitor and acid for pH control to several cooling systems from a single station. Explains problems encountered and their solutions. System described has given good corrosion control for 8 years with low labor cost averaging 1 man-hour per day for entire cooling system.

### Petroleum Producing Symposium

Aluminum Applications in the Petroleum Industry, by E. T. Wanderer, Aluminum Company of America.

Discusses present status of aluminum in the petroleum industry. Service experience is given for aluminum tubular products, pressure vessels and tankage. Structural applications are included also. Compares economics of aluminum with other materials.

Microbiology in Secondary Recovery Systems, by L. L. Wolfson, Nalco Chemical Company.

Gives general discussion of the role of microorganisms in secondary recovery systems including interrelationship of organisms with chemical scale and corrosion. Discusses life cycles and nutritional requirements of the organisms, emphasizing effects of different types of bacteria on each other. A genus of organisms, capable of hydrogen sulfide production, previously not implicated in secondary recovery problems, is described.

(Continued on Page 91)



# You're Money Ahead to MEASURE PIPE PROTECTION WITH A CALENDAR



How should pipe protection be measured? By first cost? By ease of application? By appearance?

With all the claims made for protective tapes, too often the most important consideration is overlooked—the simple point of how long and how well it will protect the pipe.

Since 1941, when TAPECOAT originated coal tar coating in tape form, this protection has proved to be the best that money can buy for combatting corrosion underground or under water. Lines in service, TAPECOATED as far back as 17 years ago, show no signs of deterioration—a record of uninterrupted performance *no other type of tape can match*. Think what this means in terms of preventive maintenance and elimination of replacement costs!

After all, hot-applied coal tar has proven over the years to be the most dependable and enduring protection. And because TAPECOAT is a hot-applied coal tar coating in tape form, it offers the same lasting protection.

A TAPECOAT sales and service engineer is available at all times to assist you on any corrosion problem and on the various applications of TAPECOAT.

**Write for complete details today.**

Manufactured and Distributed in Canada by The Tapecoat Company of Canada, Ltd., 25 Haas Road, Rexdale, Ontario.

## PROVED IN SERVICE

**...Underground or Under Water on**

<b>Pipe</b>	<b>Tanks</b>
<b>Pipe Joints</b>	<b>Tie Rods</b>
<b>Service Connections</b>	<b>Conduit</b>
<b>Mechanical Couplings</b>	<b>Cables</b>
<b>Fittings</b>	<b>Splices</b>
<b>Insulated Lines</b>	<b>Bridge Crossings</b>

TAPECOAT comes in rolls of 2", 3", 4", 6", 18" and 24" widths—sized to the job. Available also in asphalt. Where primer is desired, specify TC Primecoat, the compatible coal tar primer.



**The TAPECOAT Company**

1529 Lyons Street, Evanston, Illinois  
Representatives in Principal Cities



Bechtold



Bird



Chittum



de Laneux



Holmberg



Johnson



Jones



Kozlowski



Maradudin



Martin



Medlock



Moller



Patrick



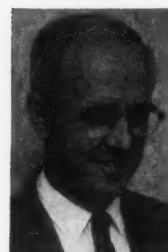
Piehl



Ritter



Wanderer



Waters

## Western Region Conference BIOGRAPHIES

**IRA C. BECHTOLD** has been associated with the process industries since he received his BS in 1930 from California Institute of Technology. He is a member of API, ISA, ACS, IRE, CNGA and AIChE and recently has established his own business as consulting engineer.

**P. G. BIRD** has been with Wright Chemical Corporation, Chicago, Ill., as research director since 1953. He has a PhD from Iowa State University. His work has been in the field of water treatment.

**JOSEPH F. CHITTUM** is research chemist for California Research Corporation where he has worked since 1946. He has been interested in practical and theoretical corrosion problems for 30 years. He has a BS from Iowa Wesleyan College and a PhD in physical chemistry from the University of Chicago.

**ROBERT L. DAVIS** is research and development engineer for Superior Oil Company. His work has been in corrosion, secondary recovery and reservoir analysis. He is past chairman and a charter member of the NACE San Joaquin Valley Section and is secretary-treasurer of the Western Region.

**E. G. HOLMBERG** is assistant supervisor of International Nickel Company's Corrosion Engineering Section. He has a ME from the Colorado School of Mines. Formerly, he was associated with E. I. duPont de Nemours & Company and Alloy Steel Products Company.

**G. B. JOHNSON** is group supervisor, plastics development and technical services, California Research Corporation. He has a MS in organic chemistry from the University of Arizona. His work has been in the fields of synthetic detergents, industrial germicides and synthetic resins, specializing in alkyd resins and unsaturated polyesters.

**DAVID T. JONES** is supervising construction foreman with Pacific Telephone and Telegraph Company, where he has worked since 1925. He has been in charge of underground cable corrosion control and design work for the company's southern region for the past 25 years. An NACE member, he is past chairman of the Western Region and Los Angeles Section.

**E. C. KOZLOWSKI**, affiliated with Jones & Keller, Inc., is technical director of the Petroleum Chemicals Division. He has a BS in petroleum engineering from the University of California at Berkeley.

**H. H. DE LANEUX** has been employed by Pacific Gas and Electric Company for 34 years and is in the corrosion engineering department of the Bureau of Tests and Inspection. He has designed and developed corrosion testing equipment and helped establish testing techniques used. He is a member of NACE.

**BERTELL E. MARTIN**, owner and manager of Ferro-Martin Company, has been active in the development of industrial coatings since 1930. He is past president of the Los Angeles Society for Paint Technology.

**HOWARD A. MEDLOCK**, a member of NACE, is associated with the corrosion engineering department of Pacific Gas and Electric Company. He has a BS in electrical engineering from California State Polytechnical College.

**GEORGE E. MOLLER** is metallurgical engineer for Oleum Refinery of Union Oil Company of California at Rodeo, Cal. He is a member of NACE and has a BS in mechanical engineering from the University of California.

**JOHN T. PATRICK** is supervisor of engineering inspection at the Oleum Refinery of Union Oil Company of California at Rodeo, Cal. He is a member of NACE and ASM and has a BS in chemical engineering from Purdue University.

**JAMES W. RITTER** is a division engineering assistant for Southern California Gas Company, where he is involved in the design and maintenance of cathodic protection systems and solution of cathodic interference problems on transmission and distribution pipelines. He has a BS in petroleum engineering from the University of Southern California.

**EDWARD T. WANDERER** is manager of the petroleum section of Aluminum Company of America's sales development division. He is a member of NACE, API and is chairman of the American Welding Society Subcommittee on Aluminum Piping. He has a BS in mechanical engineering from the University of Illinois.

**F. O. WATERS** is associated with the San Diego Utilities Department. Formerly he was corrosion engineer with Southern California Gas Company. He has a BS in electrical engineering from Kansas State College and is a member of NACE and the American Water Works Association.

**LEONARD L. WOLFSON** is associated with Nalco Chemical Company where he does research on microbiology in secondary recovery and is group leader of the microbiology laboratory. He has a MS in bacteriology from the University of Chicago.

West  
A B

Field Prob  
and Cor  
Keller, I  
Reviews p  
problems r  
describes c  
promotion  
field proble

Analysis of  
F. Chittu  
Analyzes p  
and contro  
ilities in  
Water treat  
are critical  
trol.

Cathodic I  
of Vessel  
pany.  
Discusses  
nodes and  
surfaces of  
other vesse  
cludes info  
cation and

PO  
Active  
may  
headi  
specifi

Sales Engi  
fied engin  
cathodic p  
ment worl  
product. L  
require ex  
west. Pref  
Send phot  
SION, Box

Metallurgic  
recent gra  
years' exp  
research a  
facturing  
salary req  
Research  
Division, A  
Louisville

Corrosion  
field, desig  
engineering  
experience  
SION, Box

COR  
Opportu  
control  
Prefer y  
chemical  
perience  
problem

E  
TIDE

## Western Region Conference ABSTRACTS

(Continued from Page 88)

**Field Problems Encountered With Oil Field Scale and Corrosion**, by E. C. Kozlowski, Jones & Keller, Inc.

Reviews existing oil field surface and sub-surface problems resulting from corrosion and scale. Briefly describes operational field conditions resulting in promotion of oil field scale and corrosion. Outlines field problems and accepted methods of control.

**Analysis of Oil Field Corrosion Problems**, by J. F. Chittum, California Research Corporation. Analyzes problems of classification, identification and control of corrosion with emphasis on difficulties in understanding corrosion mechanisms. Water treatment, cathodic protection and coatings are critically examined as means of corrosion control.

**Cathodic Protection Applied to Internal Surfaces of Vessels**, by R. L. Davis, Superior Oil Company.

Discusses field application of impressed current anodes and galvanic anodes to protect internal surfaces of shipping tanks, wash tanks, filters and other vessels in oil field and refinery service. Includes information on current density, anode location and methods of installation.

### Pipelines Symposium

**Practical Solutions to Cathodic Interference Problems**, by J. W. Ritter, Southern California Gas Company.

Methods of detection and correction of cathodic interference problems are discussed. Suggestions are proposed for proper maintenance of corrected problems.

### Utilities Symposium

**A Miscellany of Mitigated Corrosion Problems of a Public Utility**, by H. W. Medlock and H. H. de Laneux, Pacific Gas and Electric Company.

Presents data on corrosion problems which required unusual control measures. These include such structures as underground gas-filled, high voltage cable conduits, gas mains, cooling systems and penstocks.

**Cathodic Protection Coordination Methods and Practices**, by D. T. Jones, Pacific Telephone and Telegraph Company.

Discusses methods and practices used by a telephone company to coordinate its cathodic protection activities with other operators or owners of buried metallic pipelines or cables to minimize the effect of cathodic protection on these metallic structures.

**Corrosion Control in Water Treatment Plants**, by F. O. Waters, San Diego Utilities Department.

Lists corrosion processes confronting water treatment plants. Discusses problems encountered in installation, testing and operation of cathodic protection for rapid sand and pressure type filters. A 6-year operating experience indicates the value of cathodic protection in both types of treatment plants.

## POSITIONS WANTED AND AVAILABLE

Active and Junior NACE members and companies seeking salaried employees may run without charge two consecutive advertisements annually under this heading, not over 35 words set in 8 point type. Advertisements to other specifications will be charged for at \$10 a column inch.

### Positions Available

**Sales Engineer**: Splendid opportunity for qualified engineer with broad field experience in cathodic protection. Interested in sales development work on relatively new and accepted product. Location in or near Houston but would require extensive traveling principally in Southwest. Preferred age 25-35. Reply guaranteed. Send photo & resume of experience. CORROSION, Box 59-21.

**Metallurgical Engineer**—Excellent opportunity for recent graduate or metallurgist with up to two years' experience. Position is concerned with research on a variety of materials and manufacturing processes. Please submit resume and salary requirements to: Personnel Administrator, Research Department, Plumbing and Heating Division, American-Standard, 834 East Broadway, Louisville 4, Kentucky.

**Corrosion Engineer**—registered—experienced in field, design, sales and administrative corrosion engineering. Include complete personal and experience resume—indicate salary. CORROSION, Box 59-30

### CORROSION ENGINEER

Opportunity for challenging work in corrosion control at the world's most modern refinery. Prefer young man with degree in metallurgy or chemical engineering and up to three years' experience. Background in refinery or corrosion problems desirable but not essential. Write

Employee Relations Department  
**TIDEWATER OIL COMPANY**  
Delaware City, Delaware

### Manufacturers' Agents

**Corrosion control tape coating manufacturer** is appointing representatives in various areas. For your opportunity in this growth item submit a complete resume including areas and types of accounts covered to CORROSION, Box 59-24.

### Positions Wanted

**Patent Law**: B. S. in Met. E., LL. B. in Law. Seven years experience in research, development, and production in electrodeposition and corrosion. Member of state bar. Age 28. Married. Desire patent position. Resume on request. CORROSION, Box 59-25.

**Corrosion Engineer** experienced in practical employment of metals desires supervisory or consulting position. Chemical engineering degree. Registered engineer. Five years supervisory work, engineering organization. Fourteen years corrosion engineering. Presently engaged in corrosion research and service. CORROSION, Box—59—29

**Ph.D. Physical Chemistry**. 7 years' experience in charge of large group developing corrosion inhibitors for all phases of water and oil treatment. Age 35. Seeking responsible supervisory or managerial position and opportunity to grow with company. CORROSION, Box 59-27

**Chemist Organic Coating Formulator**. Experience in plastisol formulations plus knowledge of epoxy, polyurethane, polyester coatings. New Jersey location. Start to \$11,000.00 CORROSION—Box 59-28.



## NATIONAL and REGIONAL MEETINGS and SHORT COURSES

1959

Sept. 29-30, Oct. 1—Western Region Conference. Bakersfield Inn, Bakersfield, Cal.

Oct. 1-2—Southeast Region Conference. Jacksonville, Florida, Robert Meyer Hotel.

Oct. 5-8—Northeast Region Conference. Lord Baltimore Hotel, Baltimore, Md.

Oct. 12-15—South Central Region Conference. Denver, Colo. Cosmopolitan Hotel.

Oct. 20-22—North Central Region Conference. Cleveland, Statler Hilton Hotel.

1960

February—Canadian Region Western Division. Vancouver.

March 14-18—16th Annual Conference and 1960 Corrosion Show. Dallas, Texas, Memorial Auditorium.

Oct. 11-14—Northeast Region Conference. Prichard Hotel, Huntington, W. Va.

Oct. 19-20—North Central Region Conference. Schroeder Hotel, Milwaukee.

Oct. 25-28—South Central Region Conference. Mayo Hotel, Tulsa.

1961

March 13-17—17th Annual Conference and 1961 Corrosion Show. Buffalo, N. Y., Hotel Statler.

Oct. 9-11—North Central Region Conference. St. Louis, Chase Park Plaza Hotel.

Oct. 24-27—South Central Region Conference. Houston, Shamrock Hotel.

Oct. 30-Nov. 2—Northeast Region Conference. New York City, Hotel Statler.

1962

March 18-22—18th Annual Conference and 1962 Corrosion Show. Kansas City, Municipal Auditorium.

October 16-19—South Central Region Conference. Hilton Hotel, San Antonio, Texas.

### SHORT COURSES

1959

September 22-23—9th Annual Shreveport Section Short Course. Centenary College.

November 16-20—4th Annual General Florida Conference 1959 Corrosion Short Course. Key Biscayne Hotel, Miami.

December 7-11—University of Illinois Corrosion Control Short Course. Urbana Campus.

1960

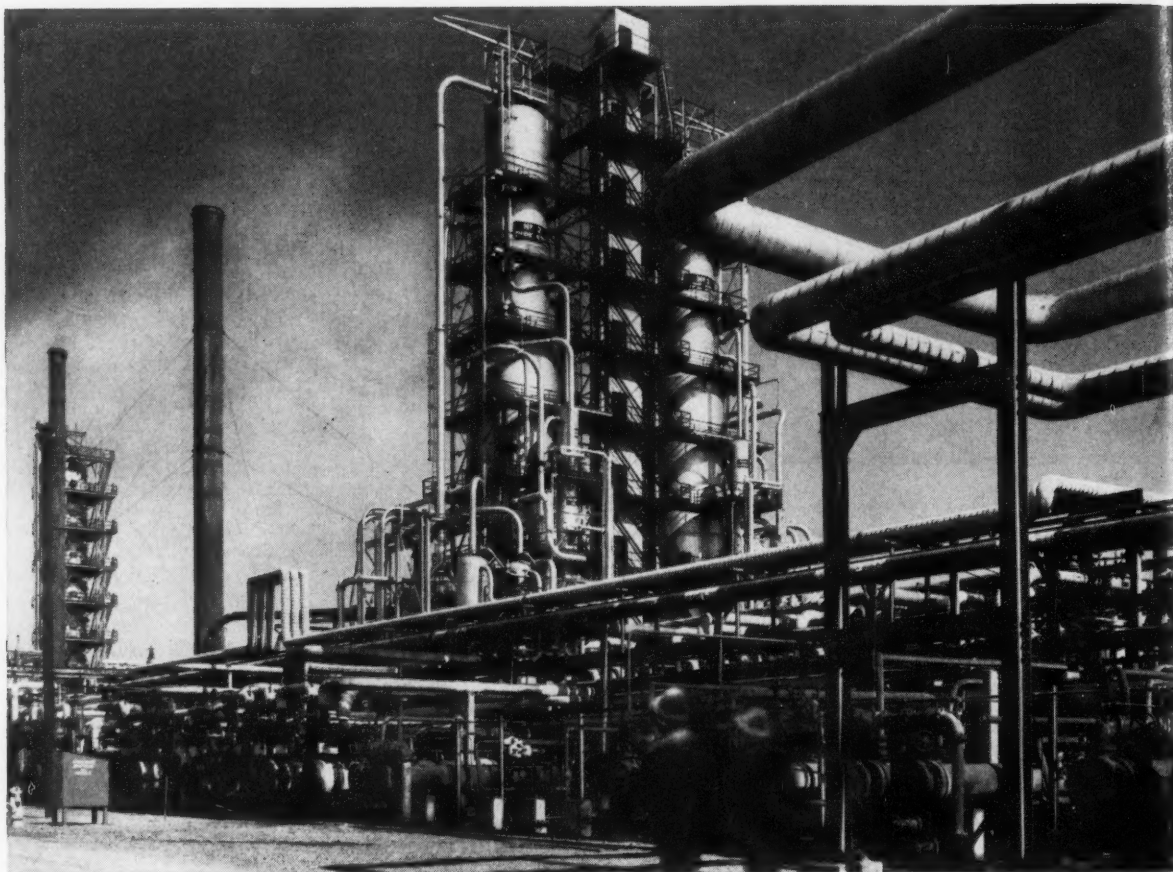
April 27-29—Portland Section Corrosion Control Short Course.

NACE's Bibliographic Surveys of Corrosion extend from 1945 to 1955. Prices available upon request.

NACE's 17th Annual Conference and 1961 Corrosion Show will be March 13-17, 1961, at the Hotel Statler in Buffalo, N. Y.



# CORROSION CONTROL?



## use Calgon Engineering Service for LOWER COSTS/BETTER RESULTS

Piping, heat exchangers and condensers are the prime targets for corrosion damage in any cooling system. This is where Calgon Engineering Service can save money and lower corrosion rates. Calgon Service starts with a survey of the system, and includes water analysis both at the source and in use, plus a review of flow rates, temperatures, equipment type and usage and all other factors. This is followed by treatment recommendations and training of plant personnel. Here is why Calgon Service can save you money and maintenance:

**LOWER CHEMICAL COSTS.** In most systems, treatment is substantially lower in cost. This is not only because of more effective treatment, but also because, in many cases, smaller amounts of chemicals can be used.

**LOWER WATER COSTS.** With more effective treatment, it is usually possible to maintain higher solid concentrations in cooling water. This means less makeup water, and consequent savings in overall water costs.

**BETTER RESULTS.** In one typical plant, water treatment in use resulted in a corrosion rate of 4 mils per year. When Calgon Engineering Service took over, corrosion rates were reduced to 1 mil per year, and chemical costs came down at the same time.

A letter or phone call will put Calgon Engineering Service to work on your particular problem. Experience with every type of water problem in all parts of the country is at your service.

### CALGON COMPANY

DIVISION OF HAGAN CHEMICALS & CONTROLS, INC.

HAGAN BUILDING, PITTSBURGH 30, PA.

In Canada: Hagan Corporation (Canada) Limited, Toronto

### Zinc A Solve

A new  
Institute  
mond, is  
anodes to  
rosion in  
Corros  
pits used  
states co  
in wire l  
area alon  
Institute

### Annual To Be

The 5th  
sponsored  
College  
September  
campus.  
be on we  
will inclu  
and alloy  
Additio  
tained fr  
York Un  
New York

### NBS F

Eight  
oxygen a  
determin  
ard samp  
Bureau  
D. C. T  
chemical  
uring gas  
steels.

### Plastic

Progre  
be the go  
ference  
Cal., spe  
fornia Se  
Engineer  
Jack F  
all Drug  
eral chair

### Packag

A 2-d  
specificat  
Universit  
Additio  
tained fr  
of Adult  
Purdue U

### Buildi

Resear  
concrete  
of the s  
Septemb  
national  
at Rotten

Over 40  
by CORRO



## GENERAL NEWS

### Zinc Anode Research May Solve Crab Pot Corrosion

A new research project at Virginia Institute for Scientific Research, Richmond, is investigating the use of zinc anodes to protect crab pots against corrosion in the east coast seafood industry.

Corrosion of galvanized iron wire crab pots used to catch blue crab in coastal states costs about half a million dollars in wire lost annually in the Chesapeake area alone, according to American Zinc Institute estimates.

### Annual Titanium Meeting To Be September 14-15

The 5th annual meeting on titanium sponsored by New York University's College of Engineering will be held September 14-15 on NYU's Bronx campus. Majority of the program will be on welding of titanium; other topics will include fabrication, heat treatment and alloying.

Additional information can be obtained from Dr. Harold Margolin, New York University, University Heights 53, New York City.

### NBS Ferrous Samples

Eight bars of ferrous materials whose oxygen and nitrogen content have been determined comprise a new type standard sample available from the National Bureau of Standards, Washington 25, D. C. These bars are used to calibrate chemical analytical equipment for measuring gas content of various commercial steels.

### Plastics Society to Meet

Progress in plastics engineering will be the general theme of a technical conference October 13-14 in Los Angeles, Cal., sponsored by the Southern California Section of the Society of Plastics Engineers.

Jack Fuller, Chemtrol Division, Rexall Drug and Chemical Co., will be general chairman of the conference.

### Packaging Conference

A 2-day conference on packaging specifications will be held at Purdue University, Lafayette, Ind., October 5-6.

Additional information can be obtained from Mark E. Ocker, Division of Adult Education, Memorial Center, Purdue University, Lafayette, Ind.

### Building Council to Meet

Research problems concerning large concrete elements in housing will be one of the subjects to be discussed at the September 21-26 meeting of the International Council for Building Research at Rotterdam, Holland.

Over 40 foreign countries are represented by CORROSION subscribers

## BOOK NEWS

**Corrosion and Deposits in Boilers and Gas Turbines.** 198 pages, 8½ x 11, paper. 1959. The American Society of Mechanical Engineers, 29 West 39th St., New York 18, N. Y. Per copy, \$6.

A comprehensive, well-referenced review of factors related to fuel deposits which cause corrosion of boilers and gas turbines. The book consists of sections devoted to general information, mineral constituents of coal, ash-forming constituents of heavy fuel oil, oxides of sulfur in boilers and turbines, physical aspects of deposition, external deposits, high temperature corrosion, corrosion of metals below 400 F and removal of solids from combustion gases.

**Technical Assistance—Services Available From IAEA.** 16 pages, 6 by 8 inches, paper. International Atomic Energy Agency, Karnthner Ring 11, Wien I, Vienna, Austria. December, 1958.

Available in English, French, Russian and Spanish, this booklet describes the kinds and fields of assistance offered by IAEA. Also discusses rules and practices governing this assistance.

**Bescherming Van Staal Tegen Atmosferische Corrosie Door Middel Van Verf.** (Protection of Steel Against Atmospheric Corrosion by Means of Paint). Publikatie No. 57. 6 by 8 inches, paper. Metaalinstituut T.N.O., Afdeling Corrosie, Postbus 52, Delft, Holland.

Published in two parts: the first gives the text in Dutch with a summary given in English; part two gives tables, graphs and photographs. Discusses performance tests on painted steel plates to determine behavior of primer on the pre-treatment of steel and influence of moisture during painting.

**Zinc Dust Paints.** A Selective Literature Review. 10 pages, 8 x 10, Paper. 1959. Translation and Technical Information Services, 32 Manaton Rd., London, S. E. 15, England. Per copy, \$1.

A selection of 100 references to zinc dust paints, including patents, from 1942 to 1959, arranged chronologically. Preface includes a brief discussion of the properties, chemistry, surface preparation problems, types of the various available formulations, keyed to references.

## NEW PERIODICALS

**Electroplating.** (In English) Published monthly by Grauer & Weil (India) Private Limited, 547, Kalbadevi Road, Bombay 2, India. Vol. 1, No. 1, May, 1959. Subscription for one year Rs. 18/-. Price per single copy, Rs. 1-50. New monthly published in India that is to be devoted to development of plating and metal finishing industries. First issue included technical articles, book reviews and discussions of industrial problems.

### British Corrosion Association Formed

The British Association of Corrosion Engineers was formed at a meeting held May 29 at South Kensington, England.

Objective of the association will be to promote dissemination of technical information about corrosion matters and to develop free interchange of information among members. Future plans for the association include establishment of suitable qualifications for corrosion engineers and standardization in terminology and techniques of corrosion control.

Technical meetings will be planned for presentation of papers, motion picture films and discussions to promote the corrosion engineer's general service to industry.

Secretary of the association can be contacted at 97 Old Brompton Road, London, S.W. 7.

### Acid Mine Water Problems To Be Discussed by SME

Problems of acid mine water will be among the subjects to be discussed at the September 23-26 joint meeting of the Industrial Minerals Division and Coal Division of the Society of Mining Engineers at Bedford Springs, Pa.

Some of the papers will be the Mine Effluent Problem, Influence of Bacteria on Formation of Acid Mine Drainage, Accomplishments of Pennsylvania State Controls for Acid Mine Waters and Disposal of Sulphur Mine Effluent.

### Indian Metal Institute To Hold Annual Meeting

The 13th Annual Technical Meeting of the Indian Institute of Metals will be held December 1-5 in Bangalore, India. The program will include a symposium on structural changes in metals and alloys given in collaboration with the Indian Institute of Science.

Additional information can be obtained from the Institute at 31 Chowringhee Road, Calcutta 16, India.

### Plastics Conference

Major aspects of plastics engineering will be included in the 16th Annual Technical Conference of the Society of Plastics Engineers, Inc., to be January 12-15, 1960, at the Conrad Hilton Hotel in Chicago.

Additional information is available from the society at 65 Prospect St., Stamford, Conn.

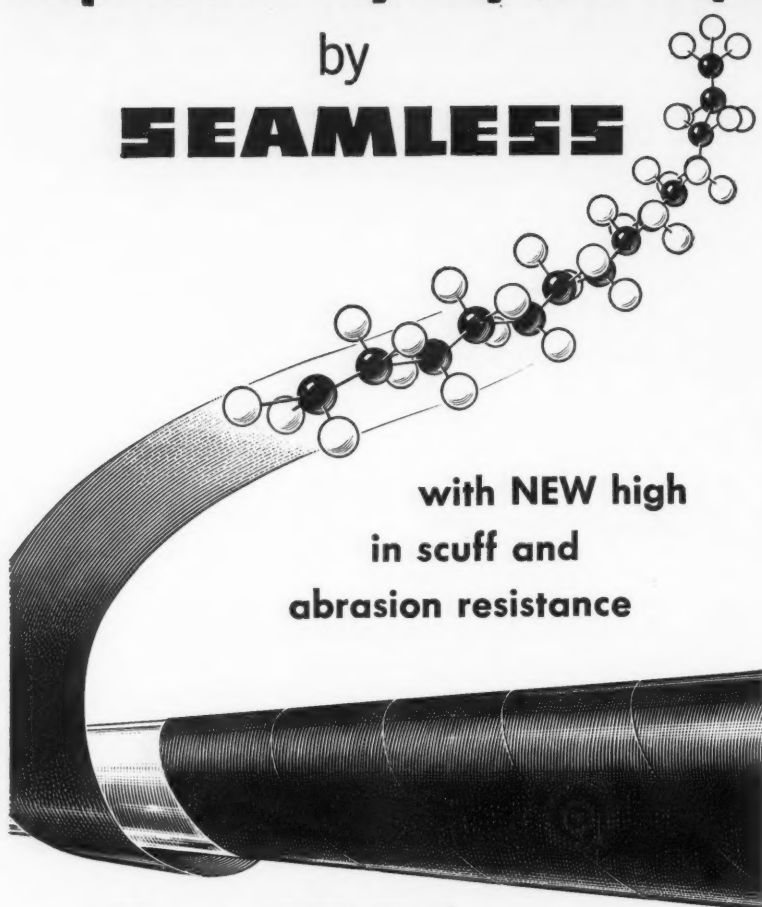
A preliminary report on ground-water resources of the Chicago Region, Illinois, (Report 1-S, 1959) has been published by the State of Illinois.

NACE's 16th Annual Conference and 1960 Corrosion Show will be held March 14-18 in the Memorial Auditorium, Dallas, Texas.

# Improved Polyethylene Tape

by

**SEAMLESS**



with **NEW** high  
in scuff and  
abrasion resistance

## Safe-T-Clad #657

A modified polyethylene tape, SAFE-T-CLAD #657 is a successful blend of high and low molecular weight polyethylenes. Developed by SEAMLESS through technical knowledge of recent advances in chemistry, this new tape has high scuff and abrasion resistance properties never before attained with plastic films for pipe coating.

Designed specifically for machine application on all sizes of piping, SAFE-T-CLAD #657 has a higher density and tougher film formulation together with a higher adhesion level and better overlap seal.

For full specifications and particulars, contact your nearest distributor or write:

SAFE-T-CLAD DIVISION  
**THE SEAMLESS RUBBER COMPANY**  
464 CONGRESS AVENUE, NEW HAVEN 3, CONN.  
A SUBSIDIARY OF THE REXALL DRUG & CHEMICAL COMPANY

## New Diesel Designs Permit Use of Lower Grade Fuels

Light grades of petroleum fuels such as kerosene are becoming so scarce and expensive because of more jet aircraft that designers are reworking old diesel designs to permit use of heavier residual fuels.

New techniques developed in diesels permit the use of fuels rated as low as Number 6. Residual fuels are all that is left of the crude oil after the lighter and more profitable products are removed at the refinery, according to a discussion held at the recent meeting of the ASME.

## Thicker Chromium Gives More Corrosion Resistance

Recent corrosion tests indicate that thicker chromium, properly applied, is one of the least expensive methods of achieving greater durability in bright chromium deposits with increased resistance to outdoor exposure.

Two new tests have been adopted by the automotive industry to evaluate performance of chromium plated exterior parts in response to public demand for higher quality in chromium parts.

## Water Purification Plant

One of the world's first salt water purification plants is being completed near Weldon, Orange Free State, South Africa. Built to purify 2.5 million gallons of mine water per day, the plant is expected to purify water at 35 cents per thousand gallons, according to the Information Service of South Africa's publication "South African Scope."

## Stadium to Be Heated

A radiant heating system is being installed in the 20,000 reserved seat section of San Francisco's new Candlestick Park Stadium. The stadium will be built of reinforced concrete with accommodations for 40,000 and future enlargement to 80,000 capacity.

## Paper Given at ASME

A paper on corrosion prevention in the process industry was presented by F. L. Whitney, Jr., Monsanto Chemical Co., who formerly was a NACE president, at the June 14-18 meeting of ASME at St. Louis, Mo.

## Radioisotope Study

Study of potential applications of radioisotopes and nuclear techniques to the iron and steel industry have been undertaken by Nuclear Science and Engineering Corp., Pittsburgh, Pa., and the American Iron and Steel Institute, New York City.

## Corrosion Research Report

Corrosion research work conducted by the Arthur D. Little Research Institute, Edinburgh, Scotland, is reviewed in the Institute's annual report for 1958. Project discussed involves chemical and physical phenomena at metal surfaces and the effect of the structure of organic additives on these phenomena.

## Cathod

Victode, ing separ rels, filter manufact materials S Fort Wo use in h pressure head mo the anode

Corrosion Springs, densed c plies, Co in tall pr well casin tems, tan footings, other ins

## Coating

Carbo Zi zinc coa Company 17, Mo., degree o eliminate fresh wat is similar has many coating p the reac slowly a give dire surfaces. becoming utes. Rai tide will coating c ance, acc

## Data-Tap

pipe coa identifical Hill-Hub Road, CI corporate stamped informati turer, pip type of r wrapped protective tion,

## Conden

Condensa mixed b in an art from Co Alleghen The arti izers to de-aerato suppleme and use eralizers stream.

## Cutting

Saffire M Alhambr



Equipment  
Services

## NEW PRODUCTS

Materials  
Literature**Cathodic Protection**

**Victode**, an insulated anode for protecting separators, heater treaters, gun barrels, filters and condensers, is being manufactured by Tejas Plastics Materials Supply Co., P. O. Box 11302, Fort Worth, Texas. The anode is for use in horizontal positions or in any pressure vessel and has an insulated head molded as an integral part of the anode body.

**Corrosion Services Inc.**, Box 787, Sand Springs, Okla., has published a condensed catalog of its services and supplies. Company engineers develop and install protective systems on oil and gas well casing, pipe lines, distribution systems, tank bottoms and internals, tower footings, steel piers, heat exchangers and other installations.

**Coatings—Organic**

**Carbo Zinc Number 11**, a new inorganic zinc coating produced by Carboline Company, 32 Hanley Ind. Ct., St. Louis 17, Mo., is designed to provide a high degree of galvanic protection and to eliminate sub-film rusting in salt water, fresh water and solvent environment. It is similar to hot dipped galvanizing and has many of the same properties. This coating provides a conductive zinc film; the reactive metal goes into solution slowly as needed when immersed to give direct galvanic protection to steel surfaces. The coating is quick drying, becoming water insoluble after 20 minutes. Rain, condensation, spray or rising tide will not damage or dissolve the coating or adversely affect its performance, according to the company.

**Data-Tape**, a coded tape integrated with pipe coating and wrapping for positive identification, has been introduced by Hill-Hubbell & Company, 3091 Mayfield Road, Cleveland 18, Ohio. The tape incorporates a kraft paper tape which is stamped at 2-foot intervals with coded information giving the pipe manufacturer, pipe wall thickness, chemistry and type of manufacture. The tape is spiral wrapped around the pipe over the last protective coating or wrapper application.

**Condensate Demineralizer**

**Condensate Treatment** by scavenger mixed bed demineralizers is discussed in an article (Publication 117) available from Cochrane Corp., 17th St. Below Allegheny Aves., Philadelphia 32, Pa. The article suggests better demineralizers to improve make-up, conservative de-aerators to reduce corrosion, use of supplementary chemicals of vapor type and use of high rate mixed bed demineralizers to scavenge impurities in the stream.

**Cutting Compounds**

**Saffire Manufacturing Co.**, 924 E. Main, Alhambra, Cal., has developed a soluble

oil and a grinding compound which are claimed to be stain and rust proof, odor free and will not affect paint or harm skin.

**De-Ironized Water**

**Sparkler-Filtrion Corp.**, North Chicago, Ill., has developed a new side-stream boiler water control system that continuously and automatically keeps boiler water clear by eliminating sludge and suspended solids. Filtration is achieved by use of a side-stream filter and filter pre-coat to reduce suspended solids to a value near zero. The units combine filtration with chemical pre-treatment, internal treatment, continuous minimum blowdown and feedwater pre-heating and de-gassing within the system.

**Barnstead Pure Water Equipment** connected in series produces 18 million ohm water in production quantities free of bacteria, organics, silica and submicroscopic particles, according to Barnstead Still and Sterilizer Co., 322 Lanesville Terrace, Boston 31, Mass. Equipment consists of sand and carbon filter, a 4-bed demineralizer, 2 stills and other heaters and filters.

**Fasteners**

**Copperply**, a pre-packaged copper covered steel wire, has been introduced by National-Standard Co., Niles, Mich., for use with tie wire reels for fastening pipe insulation subjected to salt spray and other corrosives. The wire is 16 gauge with 15 percent copper by weight to give a 1/4-mil protective copper coating around the steel core.

**Jerpak-Bayless Company**, Solon Road, Solon, Ohio, has published an illustrated brochure giving information on precision actuator screw and nut assemblies in all sizes for use in atom reactors, missiles, radar, machinery, instruments, etc. Size capabilities, thread specifications, materials and quality are discussed.

**Non-Metallics**

**Ultrasonic Grinding and Machining** of hard and brittle materials such as glass, quartz, ceramics, sapphire, carbides, hardened tool steel, ferrite and similar materials are being offered as services by Precision Glass Products Co., 6138 Beechwood St., Philadelphia 38, Pa. Bulletin UG559 describes the services available on these materials previously considered unmachinable.

**KT Silicon Carbide**, a self-bonded impervious form of silicon carbide, has operated 1700 hours in a highly corrosive application where previous materials lasted only 48 to 75 hours, according to Carborundum Company, Niagara Falls, N. Y., developer of the new material.

**Painting Equipment**

**Spray Gun** using rotary action instead of air pressure is available from Precision Equipment Co., 4407R North Ravenswood Ave., Chicago 40, Ill. The gun spins the paint at 15,000 rpm, thus eliminating nozzles, needles, valves, clogging and misting, according to the manufacturer.

**Ransburg Electrostatic Hand Gun** produces a wrap around spray which paints all sides of articles such as tubing, rod, wire, etc., from one side without overspray, according to the manufacturer Harper J. Ransburg Company, Indianapolis. Details and technical information are available from the company.

**Pipe**

**Flexible Rubber Pipe** with superior method of mating and sealing the pipe faces has been developed by General Rubber Corp., 55 Summit St., Tenafla, N. J. The single piece leakproof tube and multi-ply reinforced body have integral flanges of resilient rubber to form a seal against the pipe flanges. No gaskets are required. This patented Gen-Lok design permits metal-to-metal bolting to the pipe.

**Plants**

**Koppers Company, Inc.**, has purchased the Halowax plant of Union Carbide Corp., at Wyandotte, Mich. The plant produces chlorinated naphthalene, chlorinated paraffin and other chlorinated chemicals and resins; it will be operated by Koppers' Tar Products Division.

**Hagan Chemicals & Controls, Inc.**, is building additions to its research facilities near Pittsburgh, Pa. Space for controls and chemical product research and development laboratories plus a new pilot chemical laboratory for first run production on new products will be included.

**New High Pressure Laboratory** is being built by Eastman Kodak Company in Rochester, N. Y. It is designed for research into new chemical reactions under extra high pressures to 30,000 psi.

**Plastics**

**Safety Hats and Caps** made of fibre-glass and aluminum have been developed by Apex Safety Products, Cleveland, Ohio. A new polyethylene suspension within the hats is featured. Distributor will be Safety Division of Boyer-Campbell, 6540 St. Antoine St., Detroit 2, Mich.

(Continued on Page 96)

## NEW PRODUCTS

(Continued From Page 95)

**Fluoroflex-T Nozzle Liners** have been added to the chemically inert products made by Resistoflex Corp., Roseland, N. J. They are designed for use in the nozzle openings of reactors, vessels, condensers, pumps and other process equipment. They are inert to acids and industrial chemicals to 500 F.

**Polypropylene Film and Fiber Development** will be handled by a newly created Polyolefin Department at American Viscose Corp., at Marcus Hook, Pa. The new department will continue work on polyolefins and polymer characterization previously conducted in the Basic Research Department.

**Corrosion Resistant Valves** made of plastic are discussed in a handbook available from Chemtrol, 10872 Stanford, Lynwood, Cal. The handbook describes types of plastics used in piping systems, coupling methods of pipe to plastic valves, plastic pipe standards, installation practices, working pressures and corrosion effects of 280 chemicals on five different plastics.

**Joseph T. Ryerson & Son, Inc.**, 2558 West 16th St., Chicago 8, Ill., has added 12-inch diameter Schedule 40 and Schedule 80 to its line of Ryertex-Omicron PVC rigid, unplasticized plastic pipe. Fabricated plastic fittings are available for the 12-inch pipe.

**Plastic Spigots and Keys** for use on chemical filter presses and in applications where bulk corrosive liquids are handled. The spigots have smooth bores with no cracks to gather contamination. Developed by National Aniline Division of Allied Chemical & Dye Corp., the spigots are available from Norton Laboratories, Inc., Lockport, N. Y.

**Mill Shapes** of Polypenco Penton chlorinated polyether resins are described in a new bulletin available from the Polymer Corporation of Pennsylvania, Reading, Pa. The folder describes all availabilities and physical, chemical and electrical properties of the material.

**Extra Strength Tape Coating** made of high density polyethylene is being marketed by Polyken Sales Division of the Kendall Company, 309 W. Jackson Blvd., Chicago 6, Ill. It is a cold applied tape coating for transmission pipeline application by tensioned-spindle equipment.

**Hubbed Sewer Pipe** and hubbed perforated drain pipe made of plastic is being produced by the Plastics Division of Koppers Company, Inc., Pittsburgh 19, Pa. Marketed as Pi-Mar S (sewer) and D (drain), the new pipe with its integrated hubbing eliminates the need for a separate coupling. It can be cut with a handsaw, and no special tapering tools or adhesives are required.

**Fluoride Coatings** have been formed on copper, aluminum and other metal wires to provide exceptionally high insulation value at elevated temperatures while retaining flexibility and freedom from porosity. Research has been conducted by Bell Telephone Laboratories, 463 West Street, New York 14, N. Y.

**Byers PVC Sheets** have been used in duct work to vent corrosive acid fumes that develop during plating operations at the Zippo Manufacturing Co., Bradford, Pa. Chromic, sulfuric and hydrofluoric acids are used in the cigarette lighter plating operations. The PVC sheets were furnished by A. M. Byers Company, Pittsburgh, Pa.

**55-Gallon Drums** and lids are being injection molded by Federal Tool Corp., 3600 W. Pratt Blvd., Chicago 45, Ill. Made of white polyethylene, the drums have tight fitting, splash proof lids which fasten by means of a steel enclosure ring. The weight 10¼ lb; steel drums weigh 65 lb.

**Haveg Industries, Inc.**, 900 Greenbank Road, Wilmington 8, Del., has published Catalog P-11 which describes the applications of Haveg polyester-glass industrial corrosion resistant equipment. Physical properties, chemical resistance and typical applications are discussed and illustrated.

**Fluorglas Teflon Coated Fabrics** and adhesive tapes are described in a new folder available from Cadillac Plastic & Chemical Co., 15111 Second Ave., Detroit 3, Mich. The folder includes properties, applications and available types of the material. Strength, dielectric and moisture resistant characteristics of the fabric are charted.

### Products List

**Foote Mineral Company**, 18 W. Chelton Ave., Philadelphia 44, Pa., has published a products list which includes 60 chemicals, metals and minerals for use in such fields as chemistry, ceramics and electronics. Products included are lithium, electromanganese, zirconium, nickel, cobalt, ferro alloys and metal powders.

**Chemicals Catalog**, expanded and revised, is offered by Antara Chemicals, sales division of General Aniline & Film Corp., 435 Hudson St., New York 14. It is divided into sections on organic intermediates, acetylene derivatives and specialty chemicals such as ultra-violet light absorbers.

### Research Centers

**Bearing Technology** will be studied through new products, applications and product improvements at the new Research Center being built by Miniature Precision Bearings, Inc., Keene, N. H.

### Returning Systems

**Nalfining**, a new process to up-grade many petroleum products, has been developed by Nalco Chemical Co., 6216 West 66th Place, Chicago 38, Ill. The process is said to reduce corrosivity and improve jet fuel stability by removing contaminants such as sulfur, nitrogen or complex organic molecules not eliminated during refining.

### Soldering

**Zinc Soldering Process** for joining aluminum to itself and other metals has been developed by Alcoa, 1501 Alcoa Bldg., Pittsburgh 19, Pa. The process is a modification of the old zinc soldering process adapted for use on aluminum. Applications will be in air conditioning, automotive and electrical industries.

### Tubing

**Leaded Carbon Steel Tubing** developed for applications requiring high machinability is described in Data Memorandum No. 24 published by Superior Tube Co., Norristown, Pa. Machinability ratings for leaded and non-leaded C-1020 carbon steel are given and also chemical composition and mechanical properties.

**Bridgeport Brass Company**, 30 Grand St., Bridgeport 2, Conn., has published a 17-page brochure describing the uses of its duplex tubes in solving industrial corrosion problems.

### Welding

**Aluminum Pipe Welding** is done automatically by a new machine designed and developed by Aluminum Company of America, 1501 Alcoa Bldg., Pittsburgh 19, Pa. It is capable of producing sound welds with full penetration without the use of back-up rings, according to Alcoa.

### Wire

**Copperply Output** has been doubled by installation of new continuous plating equipment at National-Standard Company, Niles, Mich. Copperply is used for telephone conductor wire, stranded guy and ground wire and similar applications requiring strength and corrosion protection.

## MEN in the NEWS

**Lawrence L. Bott**, NACE member, has been appointed product manager in National Aluminate Corporation's division of industrial process chemicals. **Robert C. Canapary**, another NACE member, has been named product manager for petroleum industry chemicals. **Robert R. Burns** has been named manager of the corporation's product development division.

**James S. Anderson** has been appointed general manager of Babcock & Wilcox Company's Tubular Products Division.

**Francisco Chairez** has joined National Aluminate Corporation as manager of the firm's operations in Mexico City.

**W. W. Durand** has been named chief metallurgist at Crucible Steel's plant in Pittsburgh, Pa.

**William H. Dwyer, Jr.**, has been appointed manager of mid-continent and Gulf coast sales for Graver Tank & Mfg. Co., division of Union Tank Car Co. **Charles P. MacDonald** has been promoted to assistant product manager at Graver's plant in Sand Springs, Okla., and **E. G. Vail** to plant manager.

(Continued on Page 98)

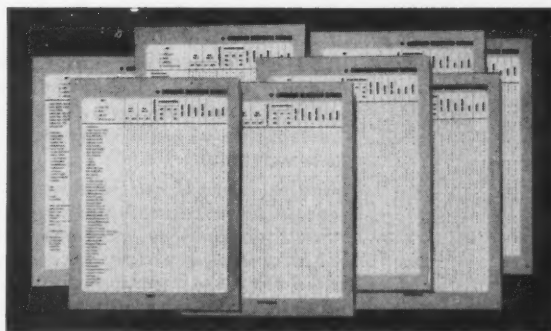
*Now you can predict service life because Byers PVC Pipe Engineering brings a factual approach to piping system design*

## FACT: 400 corrosion resistance ratings are available for Byers PVC Pipe

The ability of Byers PVC Pipe to handle various corrosive media is down in black and white. There are a number of tables available from Byers Engineering Service Department listing corrosion resistance ratings. Actual laboratory tests helped to determine these ratings. And we present them on a comparative basis with several metallic pipe materials.

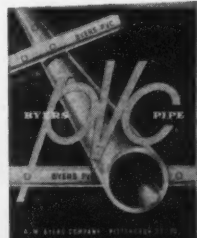
Since ratings appear only for 72°F and 140°F, these tables do not show all applicable ranges for Byers PVC Pipe. So if applications arise where you need more information, at a specific temperature and concentration, check with us.

Remember—as in metals—concentration, temperatures and stress influence corrosion rates of PVC. Type I PVC displays considerably greater corrosion resistance than Type II, which is best where high impact resistance is the prime consideration. More of this story is available from the Byers field service representative. Call him, soon. A. M. Byers Company, Clark Building, Pittsburgh 22, Pennsylvania.



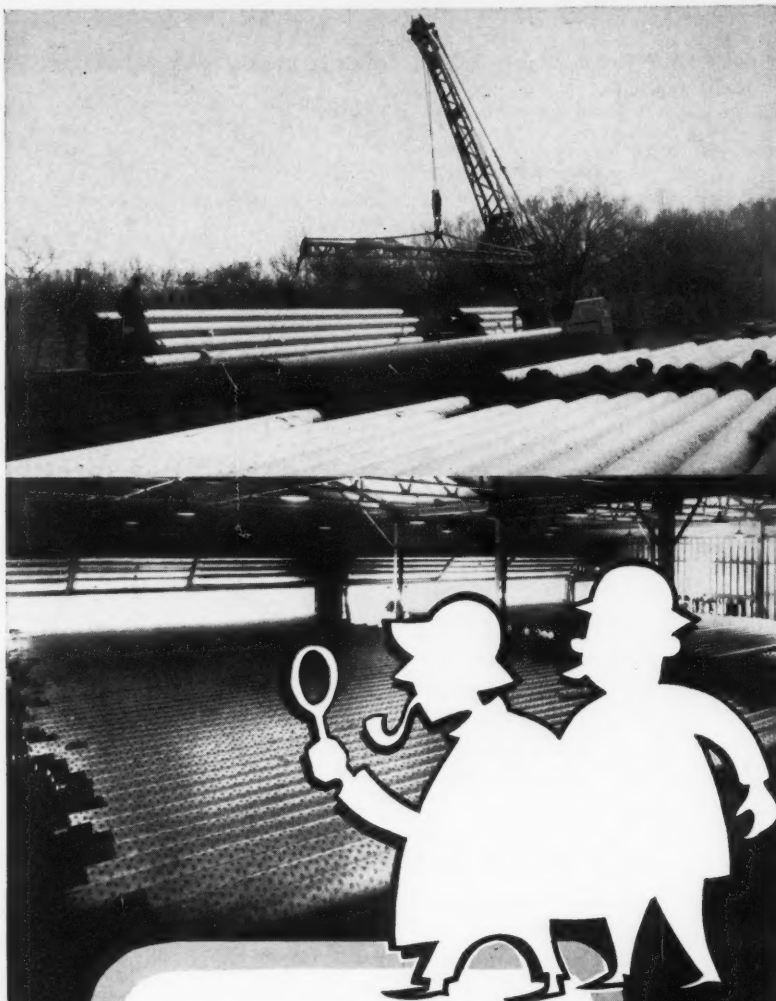
Resistance ratings are divided into four categories: E for excellent, G for good, L for limited, and U for unsatisfactory. In applications where PVC is rated as "good" and "limited" it will still display considerable resistance, in most cases higher than that of metal pipe materials.

**BYERS PVC PIPE**  
ALSO SHEET AND ROD STOCK



Write our Engineering Service Department for copy of this new 32-page illustrated catalog on Byers PVC Pipe.





## SERVICE IS NO SECRET AT SPI

No secret to our customers for they know through experience that they can count on SPI to make deliveries of perfectly processed pipe where it is wanted and when it is wanted.

And no secret to our employees for everyone at SPI is constantly aware of the fact that their primary assignment is to produce c/w pipe exactly according to SPI's rigid Standard Procedures and to ship it to our customers where and when it is needed.

Count on SPI for service . . .



**standard pipeprotection inc.**

3000 SOUTH BRENTWOOD BLVD. • ST. LOUIS 17, MO.

## MEN in the NEWS

(Continued From Page 96)

**John Fuqua** has been appointed chief plant metallurgist at Cooper Alloy Corp., Hillside, N. J.

**Russell G. Heyl, Jr.**, has been appointed chief engineer in research and development for American Metal Products Company of Detroit.

**Jerry D. Hix** has been appointed metallurgical product sales manager for Sylvania Electric Products, Inc.

**Richard G. Hume** has joined A. M. Byers Company as field service engineer at the firm's regional office in Boston.

**John T. Lurcott** has been named product engineer at Carpenter Steel Company's Alloy Tube Division, Union, N. J.

**Charles D. Preusch** has been appointed materials and process engineer at Crucible Steel Company of America, Pittsburgh, Pa.

**Richard H. Starrett** has been appointed chief production engineer at the Pfauter Company.

**Vincent C. Vesce**, technical director for Harmon Colors, Allied Chemical's National Aniline Division, Hawthorne, N. J., will present the Annual Joseph J. Mattiello Memorial Lecture at the 37th annual Meeting of the Federation of Paint and Varnish Production Clubs in Atlantic City, October 23, 1959.

**A. H. Ward**, chief research engineer at United States Steel Corp., received the 1959 Galvanizers Committee Award for distinguished service to the industry.

**Morton Z. Fainman** has been appointed director of research for Bray Oil Company.

**Robert L. Featherly**, NACE member, is manager of the newly formed electrochemical and chemical sales group of Dow Chemical Company's Magnesium Products Sales Department at Midland, Mich.

**William P. Hahn** has been appointed technical manager of Johns-Manville Fiber Glass Inc., Toledo, Ohio.

**John E. Himmelrich**, NACE member, has been named eastern regional sales manager of Pittsburgh Coke & Chemical Company's Protective Coatings Division. He succeeds **Howard F. Trusler, Jr.**, who is now sales manager of the division's regional office at Houston, Texas.

**J. A. Harmon** has been appointed manager of technical services and development for Dowell Division of Dow Chemical Company at Tulsa, Okla.

**Herbert E. Hirschland** has been elected vice president in charge of commercial development for Metal & Thermit Corp., New York, N. Y.

**J. T. Kelly** has been appointed manager of industrial sales for the Houston, Texas, paint division of Pittsburgh Plate Glass Co.



# TECHNICAL TOPICS

## Introduction

THE USE of amines in condensate cycles to reduce corrosion has become widely accepted. The filming amines which form a protective film on metal surfaces have been used with success in low pressure plants. In an attempt to control corrosion in a relatively high pressure plant, filming amine has been used for a period of two years at a large electric utility plant.

## Description of Plant

This electric plant consists of two topping units operating at 1250 psig, 900 F, 250 psig exhaust and four low pressure condensing turbines. Each topping unit is supplied with steam from three open-pass slag tap boilers. The newer No. 6 Unit has a spray type de-aerating heater; No. 5 Unit is a closed system with deaeration in hotwell but no deaerating heater. Exhausts of the two high pressure topping turbines go into a common header and the condensate from four low pressure turbines discharges into a common header.

Condensers are provided with steam jet ejectors and after-drips are discharged to waste to keep ammonia in the system low. Make-up is provided by evaporators which are fed by sodium zeolite softened Ohio River water. The pH of the condensate before use of filming amine ran from 6.5 to 8.0 and averaged about 7.3. Oxygen content in the condensate as shown by a Cambridge dissolved oxygen analyzer is normally 20 to 30 PPB. During the period of testing, one low pressure unit generally was removed from service each night. Oxygen is high during start-up in the morning, reaching values as high as 17 ppm. Sodium sulfite is fed continuously at the hotwell to provide a low residual in the boilers.

## Iron Corrosion Rates Before Treatment

A testing program was started in 1953 to obtain data on the corrosion rate of iron specimens in these units. Because No. 1 low pressure unit and its associated system was without deaerating heater, use of this unit and cycle was made to provide the best information on the severity of corrosion. Because of the problems with condenser leakage, analytical methods of testing for iron and copper probably would provide information hard to correlate. Consequently, corrosion test specimens placed in the operating cycle were used. These specimens consisted of steel and copper strips mounted on 1/4-inch pipe plugs insulated from the plug by plastic mounting strips. These plugs could be inserted in specimen locations in standard couplings or tees where the specimen could project into the condensate flow path.

Figure 1 shows a schematic diagram of the low pressure condensate cycle and the location of seven test specimens. This portion of the cycle contains one

heater which raises the condensate from condenser temperatures to about 150 F. Test specimens placed in the cycle when the unit was off overnight remained in the cycle for 30 days. After removal, they were cleaned, weighed and corrosion rate calculated. The following tables give these results as milligrams per square decimeter per day.

Table No. 1 shows the results of four testing periods from 1954 to 1956 using iron specimens. Several other tests were conducted, but these four were used because they were the most complete tests available. Table No. 1 also shows the average corrosion rates of the four test periods.

One other complete test was made in January, 1956, which is not given in Table 1. During this period the Ohio River was very low and organic material was exceptionally high causing high ammonia values in the condensate. This ammonia caused elevated pH's not normally present in this system. Therefore, these results would not indicate normal corrosion conditions. As expected on steel specimens, the normal corrosion rate was cut almost in half by the ammonia present during this month.

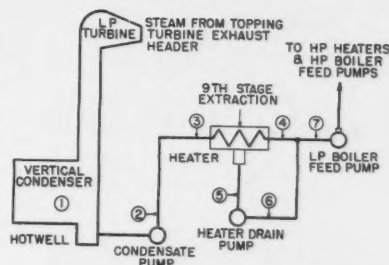


Figure 1—Condensate cycle of an electric utility plant.

## Abstract

Covers the use of filming amine to protect turbines and condensate systems against carbon dioxide and oxygen corrosion at an electric utility plant. Effects on corrosion test specimens in various locations before and after use of filming amine is described. Other data pertaining to the effects of the amine on turbine erosion-corrosion are given in tables 5.8.4

## Filming Amines Control Corrosion In Utility Plant Condensate System\*

Results of the first two test periods on Specimen No. 4 were not used to calculate average corrosion rates. Some error must have been made in the program; the corrosion rate at this location logically should be almost the same as the three other specimens around the heater. Results of the last two test periods indicate that this is the case.

The results show that the corrosion rates especially around the 9th stage heater were excessive. Corrosion rates in low temperature area around the condenser were not excessive. Inspection of the test specimens indicated that the primary attack on Specimens 1, 2, 3, 4

and 7 was etching or carbon dioxide attack; Specimens 5 and 6 showed pitting as the primary attack. This pitting probably was caused by oxygen leakage at the heater since there has been a history of oxygen leakage at this point.

## Filming Amine Treatment

An octadecylamine derivative was introduced into all cycles (Table 1 and Figure 1) in August, 1956. Feed rate of the initial feed was 1 ppm based on make-up. This rate was increased gradually until a feed rate of 5 ppm based on make-up was reached in February,

(Continued on Page 100)

TABLE 1—Condensate Cycle Iron Corrosion Rate\* Without Treatment

Specimen and Location	Test 1	Test 2	Test 3	Test 4	Avg. Rate
1 Condenser Vapor Space.....	8.3	..	5	10	7.8
2 Condensate Leaving Hotwell.....	16	19	12	18	16
3 Condensate to 9th Stage Heater.....	17	19	11	16	16
4 Condensate Leaving 9th Stage Heater.....	10**	6**	40	51	46
5 Heater Drain Pump Suction.....	48	40	42	51	45
6 Heater Drain Pump Discharge.....	52	47	42	71	53
7 Low Pressure Boiler Feed Pump Suction....	41	33	43	39	39

\* Corrosion rate measured in mg/dm<sup>2</sup>/day.

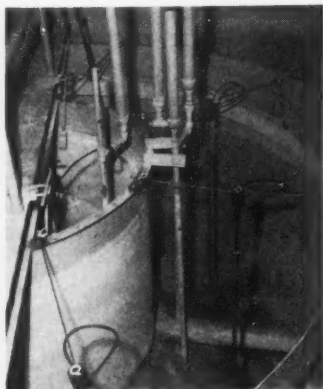
\*\* Not used to calculate average corrosion.

# RECTIFIERS

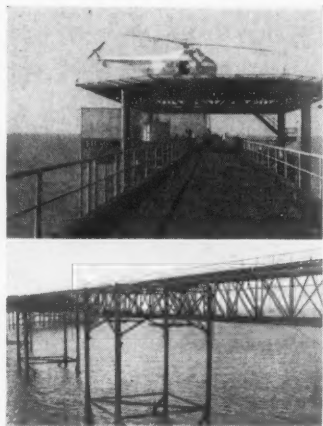
for **SPECIALTY**  
cathodic protection  
systems

Manufactured  
by and for

**CORROSION  
ENGINEERS**



Installed in water flood equipment



Used on  
offshore  
platforms

Designed for  
elevated  
water tanks



Write Today for  
Free Catalog

**CORROSION RECTIFYING CO., INC.**  
5310 Ashbrook MO 7-6659  
P. O. Box 19177 HOUSTON, TEXAS

## Filming Amines—

(Continued From Page 99)

1957. A rate of 5 ppm in make-up is equivalent to about 0.2 ppm in the condensate. Feed is continuous at hotwell pump discharge.

Inspections of the cycle indicate that a non-wettable film was present in the condenser and after-condenser of jet ejectors. No buildup of amine was noted in after-condensers. Terminal temperature differences at the heaters showed some improvement especially in the low pressure heaters. No heaters have been physically inspected since the feed of amine.

### Iron Corrosion Rates After Treatment

Results of four tests after the feed of amine are shown in Table 2. These tests are of 30 days' duration and at the constant feed of 3¼ lb per day amine feed or 5 ppm based on make-up. Except for one test of Specimen 7, results were excellent. The corrosion rate at all locations in this low pressure condensate cycle was low. The percent reduction of corrosion based on the average corrosion rate is shown in Table 3. The corrosion reduction around the 9th stage heater drain pump was significant since this area had heavy oxygen corrosion.

## Copper Corrosion

Although copper corrosion had never been a problem, the effects of the amine against the copper in the cycle were checked. Consequently, copper specimens were installed in some of the tests. Table 4 shows results of the copper specimen tests. Little data was collected before the use of amine in these cycles, but, as expected, the tests showed the copper corrosion rate was satisfactory before the use of amine.

Two complete tests run with copper specimens after the use of amine indicated that copper corrosion is extremely low. Although results before and after amine treatment are difficult to compare, the data available indicated that copper corrosion rate had not been increased and probably had been decreased.

### Turbine Corrosion-Erosion

Inspection of the newly rebuilt low pressure No. 2 turbine in July, 1956, after two years' operation indicated a serious erosion-corrosion problem in the machine's last stage. After the turbine was rebuilt, its improved efficiency caused greater water quantities in the last stages. This low quality steam caused heavy metal losses on the unstalled blades. Depth of penetration of the last stage wheel was as much as ¼-inch over 12 to 15 inches of blade

(Continued on Page 103)

TABLE 2—Condensate Cycle Iron Corrosion Rate After Treatment\*

Specimen and Location	Test 1	Test 2	Test 3	Test 4	Avg. Rate
1 Condenser Vapor Space.....	.93	5.1	2.0	2.4	2.6
2 Condensate Leaving Hotwell.....	6.3	2.9	4.3	2.6	4.0
3 Condensate to 9th Stage Heater.....	4.1	3.6	2.5	4.8	3.8
4 Condensate Leaving 9th Stage Heater.....	2.2	4.5	3.5	4.4	3.7
5 Heater Drain Pump Suction.....	4.8	2.0	1.5	.68	2.2
6 Heater Drain Pump Discharge.....	3.4	1.9	.19	.25	1.4
7 Low Pressure Boiler Feed Pump Suction....	1.8	1.2	.43	14**	1.1

\* Corrosion rate measured in mg/dm<sup>2</sup>/day. Amine feed was 3¼ lb per day.

\*\* Not used to calculate average corrosion rate.

TABLE 3—Condensate Cycle Iron Corrosion Rate Averages

Specimen and Location	Average Rates		% Reduction Corrosion
	No Treatment	With Treatment	
1 Condenser Vapor Space.....	7.8	2.6	67
2 Condensate Leaving Hotwell.....	16	4.0	75
3 Condensate to 9th Stage Heater.....	16	3.8	76
4 Condensate Leaving 9th Stage Heater.....	46	3.7	92
5 Heater Drain Pump Suction.....	45	2.2	95
6 Heater Drain Pump Discharge.....	53	1.4	97
7 Low Pressure Boiler Feed Pump Suction....	39	1.1	97

TABLE 4—Condensate Cycle Copper Corrosion Rate\*

Specimen and Location	No Treatment		After Treatment	
	Test 1	Test 2	Test 3	Test 4
1 Condenser Vapor Space.....	.5	.8	.34	.75
2 Condensate Leaving Hotwell.....	..	..	.16	.05
3 Condensate to 9th Stage Heater.....	..	..	.19	.07
4 Condensate From 9th Stage Heater.....	..	..	.23	.13
5 Heater Drain Pump Suction.....	..	..	.48	.34
6 Heater Drain Pump Discharge.....	2.8	2.9	.31	.45
7 Low Pressure Boiler Feed Pump Suction....	..	1.8	.05	..

\* Corrosion rate measured in mg/dm<sup>2</sup>/day.



never  
amine  
were  
cimens  
Table  
ecimen  
before  
out, as  
copper  
before  
  
copper  
e indi-  
remely  
l after  
mpare,  
copper  
reased

lt low  
1956,  
ated a  
in the  
turbine  
ciency  
in the  
steam  
ne un-  
ion of  
uch as  
blade

Avg.  
Rate

2.6  
4.0  
3.8  
3.7  
2.2  
1.4  
1.1

%  
uction  
rosion

67  
75  
76  
92  
95  
97  
97

ment

Sodium Chromate

Test 4

.75

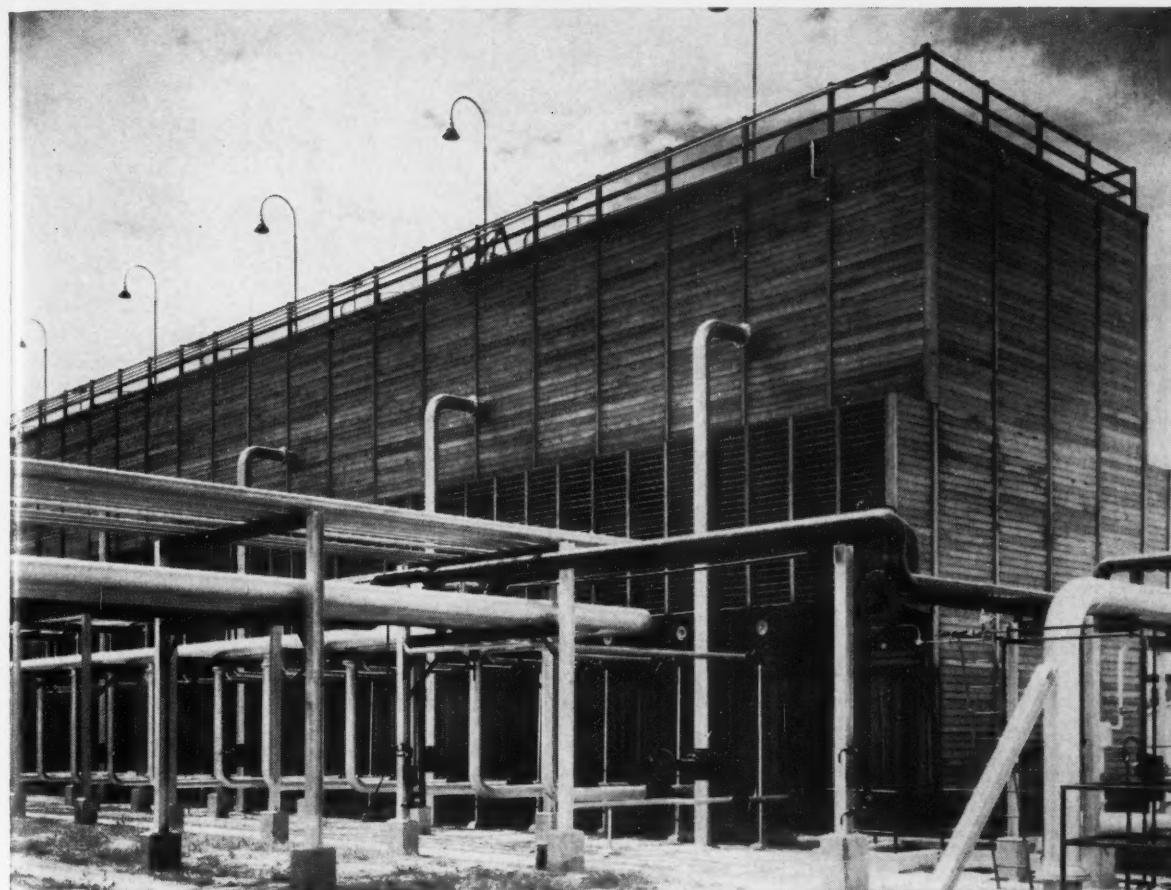
.05

.07

.13

.34

.45



## CHROMATE COMPOUNDS STOP CORROSION *before it starts!*

Long before the first drop of water contacts metal in any large recirculating water system, steps should be taken to prevent corrosion.

Early in the design stage, plan on adding a chromate inhibiting compound to recirculating water—from the moment operation starts. That way, clean metal stays clean. Chromate inhibiting compounds will also

arrest corrosion in older systems that have been operating without protection, even where rust and scale make it more difficult for inhibitors to reach and protect the metal.

Chromates work two ways: they make waters non-corrosive while making metal surfaces corrosion-resistant. Chromate inhibiting compounds are easy and inexpensive to

use. Since conditions and equipment vary, a variety of compounds are available to meet individual requirements.

For the names of manufacturers of corrosion inhibiting compounds containing Mutual Chromium Chemicals, or information on Mutual Chromium Chemicals, mail the coupon below.

### Mutual® Chromium Chemicals

Sodium Bichromate  
Sodium Chromate  
Chromic Acid

Korean (one-bath chrome tan)

Potassium Bichromate  
Potassium Chromate  
Ammonium Bichromate

**SOLVAY PROCESS  
DIVISION**

61 Broadway, New York 6, N. Y.



Mutual Chromium Chemicals are available through dealers and SOLVAY branch offices located in major centers from coast to coast.

#### MUTUAL CHROMIUM CHEMICALS SOLVAY PROCESS DIVISION

Allied Chemical Corporation  
61 Broadway, New York 6, N. Y.

Please send:

- ☐ List of manufacturers of corrosion inhibiting compounds.  
☐ Booklet "Mutual Chromium Chemicals."

Name \_\_\_\_\_ Position \_\_\_\_\_

Company \_\_\_\_\_

Street \_\_\_\_\_

City \_\_\_\_\_ Zone \_\_\_\_\_ State \_\_\_\_\_

11-89



Painting foreman at large  
East Coast shipyard says:

## "We've tried lots of coatings: none equals Bitumastic for salt-water exposure"

This yard, one of the largest on the Eastern Seaboard, first tried a Bitumastic coating system for the protection of floating dry-dock wing-walls in 1957. The excellent performance of the coatings—and the firm's evaluation of competitive materials—led to the specification of the same system for the yard's newest dock. The two docks, old and new, are shown at left and right in the above illustration.

The yard's painting foreman notes that the two-year old Bitumastic coating system, with a total thickness of 60 mils, has been unaffected by constant wetting and drying cycles under salt-water

exposure. Minor mechanical damage will not require touch-up for another two years.

Do you have a salt water corrosion problem on dockside facilities, off-shore rigs or production equipment in swampy ground? If so, it's likely that Bitumastic coatings can help you reduce corrosion costs. The coupon will bring you more information . . . or the personal attention of the Koppers representative or authorized Bitumastic industrial distributor near you. Koppers Company, Inc., Tar Products Division, Pittsburgh 19, Pennsylvania. In Canada, Koppers Products, Ltd., Toronto.

District Offices: Boston, Chicago, New York, Los Angeles, Pittsburgh and Woodward, (Birmingham, Ala.)

Koppers Company, Inc.  
Tar Products Division  
Dept. 100H, Pittsburgh 19, Pa.

Gentlemen:

Please send me additional information on Bitumastic Protective Coatings for industrial corrosion prevention.

Name \_\_\_\_\_ Title \_\_\_\_\_

Firm \_\_\_\_\_

Address \_\_\_\_\_

City \_\_\_\_\_ Zone \_\_\_\_\_ State \_\_\_\_\_



# BITUMASTIC

REG. U. S. PAT. OFF.

## COATINGS AND ENAMELS

Another fine product of COAL TAR

SAL  
th  
tunity  
dama  
e pos  
n atel  
A v  
2-in  
u ed  
secti  
- 6.0  
level  
ctor  
or eff  
secti  
Th  
1 to

Film

length  
loss v  
diaph  
path.  
was  
starte

In  
spect  
amin  
half  
turbine  
not  
blade  
on No  
after  
phrag  
metal  
Exha  
treme  
Many  
pearl  
spect  
non-v  
areas  
path,  
prote  
troub  
film  
stea  
amou  
not s

Th

follow  
1. I  
tive f  
sure  
evid  
pipin

2. carb  
3. tecti  
stand  
tecti  
n thi  
4. fect  
alloys  
such

## Offshore Platform Shows

# Corrosion Rate of Carbon Steel In Gulf of Mexico Exposure\*

**S**ALVAGE OF an offshore platform in the Gulf of Mexico provided an opportunity for close inspection of corrosion damage to carbon steel which had been exposed in 20-foot water for approximately nine years.

A vertical section 1 by 12 feet from a 24-inch OD steel conductor pipe was used to check the corrosion rate. This section included surfaces exposed from -6.0 inches to +11.5 feet mean Gulf level. A scissors caliper with a dial indicator was used to measure the average or effective thickness across the removed section.

The average corrosion rates taken at 1 to 12-foot elevations (Figure 1) are

considered to be average rates for uncoated carbon steel not subjected to mechanical damage such as barges, boats, etc., and submerged in the Gulf of Mexico.

Maximum average corrosion rate (0.021 ipy) was from 9.5 to 10 feet mean Gulf level. On submerged dolphin piling templates which were not cathodically protected, maximum corrosion rate was 0.018 ipy.

★ Revision of a paper titled "Corrosion Rate of Carbon Steel in the Gulf of Mexico" by Dean Patterson, Phillips Petroleum Co., Bartlesville, Okla., submitted April 6, 1959, for publication.

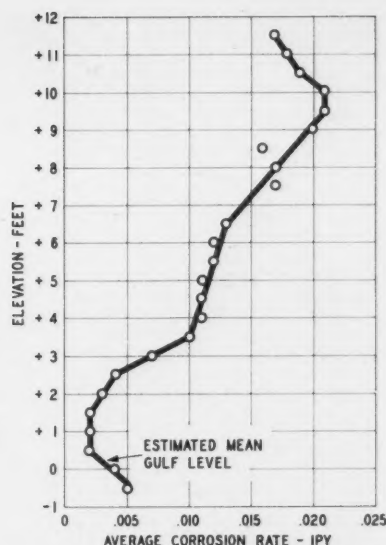


Figure 1—Corrosion graph showing relation of corrosion rate of 24-inch carbon steel conductor pipe exposed on an offshore platform in the Gulf of Mexico.

## Filming Amines—

(Continued From Page 100)

length. In addition, considerable metal loss was noted on diaphragm blades and diaphragm ledges out of the wet steam path. Immediately after this problem was discovered, amine treatment was started.

In April, 1958, No. 1 turbine was inspected two years after rebuilding. Full amine treatment had been used for over half this period. Inspection showed the turbine erosion-corrosion problem had not been arrested. Metal loss on the blades of this machine was as great as on No. 2 machine inspected in July, 1956, after two years with no amine feed. Diaphragm and diaphragm ledges showed metal loss similar to the No. 2 turbine. Exhaust hood showed areas where extremely heavy metal loss was evident. Many areas had the bright metal appearance of active corrosion. Close inspection showed little evidence of any non-wettable film in this area. In some areas on the hood out of the main steam path, some film was apparent, but little protection was provided for the major trouble areas in the turbine. Either the film was not stable in the area where steam velocities were great or the amount of amine in the wet steam was not sufficient to form a protective film.

### Conclusions

The use of filming amine indicated the following conclusions.

1. Filming amine will form a protective film on metal surfaces in low pressure condensate systems. This film is evident in condensers and feedwater piping.
2. The film gives protection against carbon dioxide and oxygen corrosion.
3. Filming amine treatment offers protection to systems used frequently for stand-by service because it offers protection against oxygen which is present in this type service.
4. Filming amine has no adverse effects on copper and copper bearing alloys. It may offer some protection to such alloys in condensate systems.

5. Filming amine does not cause objectionable dislocation of previously deposited corrosion products when feed rate is increased slowly.

6. Filming amine, when fed at rates sufficient to protect condensate systems, does not offer proper protection to wet areas of turbines.

### Acknowledgments

The author is indebted to Hall Laboratories and their representatives who provided specimens and much of the analytical work necessary to collect this data. Thanks are also extended to all the many people at West End Station for their help in collecting all the data which made this presentation possible.

Discussion by Wayne P. Ellis, Benjamin Foster Co., Philadelphia:

What is the chemical nature of the film formed by the amine?

Reply by Edward E. Galloway:

I do not know of any investigations that have been made to determine the chemical nature of the film.

Discussion by Richard D. Neidhard, Cincinnati:

What method or way did you tell that the filming amine was actually present on the metal?

Reply by Edward E. Galloway:

A heavy film can be detected by feel. A thin film, such as is generally found on condenser tubes, can be detected with water. Water placed on these tubes will not adhere to the metal but will run off or form droplets similar to water on a waxed surface.

Discussion by Homer L. Shaw, Youngstown Sheet & Tube Co., Youngstown, Ohio:

Have you found any evidence of stress corrosion cracking in the lines from use of amines?

Reply by Edward E. Galloway:

We have found no evidence of stress corrosion cracking in any lines with the use of filming amine.

4th Annual Corrosion Control Short Course sponsored by the Miami Section will be held November 16-20 at the Key Biscayne Hotel, Miami, Florida.

The University of Illinois Corrosion Control Short Course will be held on the Urbana Campus December 7-11.

## CUT PLANT MAINTENANCE COSTS



with

**KERPON  
PROTECTIVE  
COATINGS**

Phenolic, Epoxy, Latex Resins—  
All Type Applications!

MINIMIZES CORROSION in Tanks—Vats—  
Pipes—all Containers, any Exposed  
Metal

PROTECTS AGAINST highly concentrated  
Acids—Fumes—Caustics—Alkalies  
Abrasives—Heat

PROVEN SUPERIOR in Resistance—  
Flexibility—Long Life—Reduction of  
Deterioration Under the Most Extreme  
Corrosive Conditions

**KERPON PROTECTIVE COATINGS**  
Faster to Apply—Cost Less

For an Easy Solution to Your  
Corrosion Problems—write

**KERR CHEMICALS, INC.**  
DES PLAINES, ILLINOIS • P. O. BOX 189



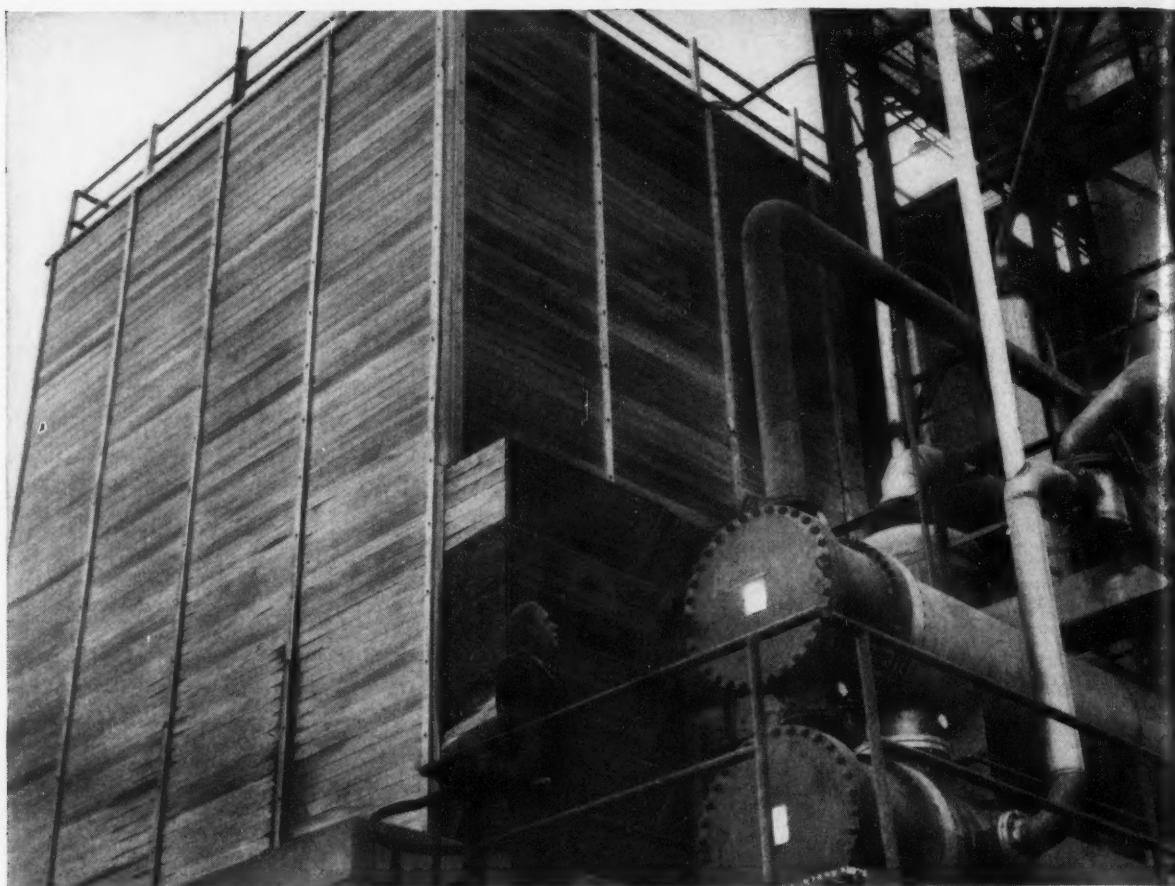


Photo and information, courtesy of Chemical Processing Magazine

## Going two years! Nickel Stainless Steel doubles life of nitrogen oxide exchangers

*...has already saved thousands with more savings to come*

Until recently, corrosion of heat exchangers at the Cooperative Farm Chemicals Association plant in Lawrence, Kansas was an acute problem. Sometimes the exchangers, used to cool nitrogen oxides, had to be completely replaced within a year... at a cost of thousands of dollars.

Now comes word that nickel-containing Type 304 stainless steel exchangers... the ones shown above... have lasted two years. And they are expected to be on-the-job for some time to come. The units were made by Western Supply Company of Tulsa, Oklahoma.

### Temperature is reduced 410° F


As a step in the production of 57% nitric acid, the units take nitrogen oxides derived from ammonia oxidation and cool them from 500° F to 90° F. Each exchanger has 1305 square feet of cooling surface. Surface is obtained with 473, 3/4-inch tubes. Tubes are Type 304L stainless steel. With the exception of channel side and external bolting, shells are also Type 304.

### Other savings

In addition to eliminating early replacement cost, the use of nickel-

containing stainless steel in these exchangers is materially reducing general maintenance and down time.

In thousands of other chemical processing applications, nickel-containing stainless steels are doing as much or more. Contact your fabricators about these useful steels. Or go to the producers of stainless steel for information. Ask them to suggest places where a stainless steel specification can save money in your plant.

**THE INTERNATIONAL NICKEL COMPANY, INC.**  
67 Wall Street  New York 5, N. Y.

# INCO NICKEL

**NICKEL MAKES ALLOYS PERFORM BETTER LONGER**

## Material Selection in

## Chemical Milling Process\*

CHEMICAL MILLING has been developed during the past five years as a production method by aircraft manufacturers. Many parts produced by chemical milling are not producible by any other technique.

Rather than being a destructive force, corrosion has been controlled in this milling process to produce intricate parts with blue-print tolerances from such diverse metals as aluminum, magnesium, titanium and various stainless and alloy steels.

In the chemical milling process, parts are first treated to obtain a chemically clean, uniform, dry surface. Then they are masked by applying a protective coating using such techniques as dipping, spraying or flow coating.

## Mask Composition

Mask composition varies according to the exposure to be encountered during subsequent etching. Masks based on the elastomer neoprene have given good protection in the aluminum, magnesium and titanium systems. The steel etchant system, however, because it contains a mixture of hot oxidizing mineral acids, is the most aggressive etchant and required superior resistance in the mask. Vinyl plastisol has been used, but the critical oven curing schedules have been

a handicap. New products based on hydrocarbon elastomers have shown good promise and have much simpler baking schedules.

Masks for use in the process must have unusual corrosion resistance properties. Because dipping is a popular method of application, a two-part product for the mask is unacceptable. The mask must be capable of being applied by brush, spray, dip, roller or flow-coat. Drying time between coats must be minimal, preferably not over 30 minutes, and dry film build-up should be 2 to 3 mils per coat. Oven curing is an unwanted complication. On steel parts, however, baking is compulsory to develop the required resistance to the etchant's attack.

Adhesion of the cured film to the metal substrate is perhaps the most critical property of the mask. Adhesion must be low enough to permit easy hand stripping yet high enough to provide good protection from physical damage in handling.

After etching has proceeded to the desired depth, the part is removed from the etch bath and rinsed in water.

The final step is removal of the mask.

Table 1 gives the cleaner, deoxidizer and etchant solutions for aluminum, magnesium, steel and titanium systems with the tank material used for each system.

## Materials Used In Steel System

In the steel system, rigid PVC piping has given good service in resistance to

chemical attack but requires careful support to minimize structural strain. PVC is also subject to accidental breakage by impact.

Steel pipes and fittings lines with glass or vinylidene chloride are resistant to etchant attack and are structurally strong. All such connections should be flanged.

Heat exchanger construction may be of epoxy impregnated carbon, glass or tantalum, depending on such factors as size of installation, whether the exchanger is placed in the tank or externally in the piping, source of heat, type of circulation, etc.

Pump construction in the steel system for circulation of the etchant can be epoxy impregnated carbon or glass lined steel.

Because some of the acid components from the etchant bath will escape the exhaust system (see Footnote 2 in Table 1) and enter the room atmosphere, interior structural surfaces should be protected with a high quality maintenance coating such as a 5-mil dry film thickness of vinyl paint.

Racks for holding parts immersed in the steel etchant may be made of mild steel coated with a vinyl plastisol such as is used on plating racks.

## Materials Used In Titanium System

In the titanium system, piping may be of rigid PVC or vinylidene lined steel. Pumps and heat exchangers can be constructed of epoxy impregnated carbon. Exhaust system for fumes can be vinyl plastisol lined mild steel.

Like the steel system, acid vapors from the titanium etching bath will attack structural members. A 5-mil coating of vinyl film or the equivalent should be used.

## Conclusion

Through careful choice of proper protective materials, highly aggressive solutions used in the chemical milling process can become new tools capable of producing aircraft and missile parts which are unproducible by other processes.

## Technical Topics Scheduled For September Publication

Methods of Installing Cathodic Protection Anodes for Offshore Structures, by Wayne A. Johnson and James T. Condry

Case Histories of Differential Aeration Corrosion in Underground Telephone Cables, by David T. Jones

Mechanisms and Some Theoretical Aspects of Stress Corrosion Cracking of Austenitic Stainless Steels, by W. B. Brooks

Rapid Field Measurement of Sub-Surface Corrosion of Aluminum, by Hugh P. Godard

TABLE 1—Chemical Milling Systems

Material Etched	Cleaner			Deoxidizer			Etchant		
	Material	Temp	Tank Material	Material	Temp	Tank Material	Material	Temp	Tank Material
Aluminum	Silicated or non-silicated alkaline	170-190 F	Mild Steel	Acidified mixture; sulfate and chromate salts		PVC, 18-8 Stainless Steels	Contains caustic soda <sup>1</sup>	190-200 F	Mild Steel
Magnesium	Alkaline	200 F	Mild Steel				Dilute sulfuric acid with organic and inorganic additives <sup>1</sup>	120 F	PVC Monel Vinyl plastisol
Steel	Alkaline	200 F	Mild Steel				Aqua Regia containing dissolved metal <sup>2</sup>	150 F	Rigid PVC and acid proof brick with plasticized PVC membrane, or poly-fluoro-ethylenes
Titanium	Alkaline	200 F	Mild Steel				Chromic and hydro-fluoric acids mixture	115 F	Mild Steel lined with plasticized PVC

<sup>1</sup> A mist develops at the surface of the solution from the hydrogen which entrains an appreciable amount of caustic. Exhaust ventilation is necessary with vinyl plastisol coating on the duct work.

<sup>2</sup> Fumes from the etchant surface contain hydrochloric acid and oxides of nitrogen—both noxious and corrosive. Duct work in the exhaust system can be mild steel lined with vinyl plastisol.



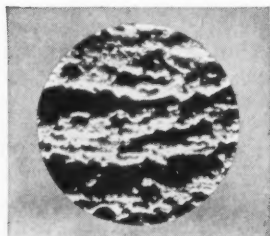
*save on steel! save on acid! save on pickling costs!*  
*... with Amchem Rodine!*

Exhaustive comparison tests with competitive materials prove time and again Amchem Rodine's superiority in performance, with substantial savings in costs, acid and steel in the bargain.

Amchem Rodine pickling acid inhibitors retard the attack of acid on the metal without lessening its capacity to remove scale. Not only do they save in metal and acid, but they reduce production costs and their efficiency

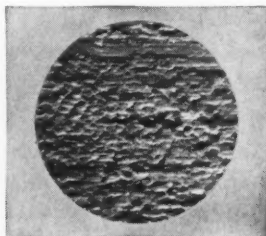
improves the quality of the pickled product as well.

If you are now using an inhibitor in your pickling bath, you'll want to investigate the three way savings highly concentrated Amchem Rodine can effect. Find out now about this superior Amchem inhibitor development, ask about our full time technical and engineering assistance program, and check Amchem for service you can depend on long after the sale!



**Effect of Uninhibited Acid**

This microphotograph of a low-carbon sheet steel panel pickled in uninhibited sulfuric acid shows deep etching and the pitted character of the surface after 5 minutes in the solution.



**Effect of RODINE-INHIBITED Acid**

Panel pickled for 5 minutes in Rodine-inhibited sulfuric acid, then microphotographed. Only scale pockets and roll marks are visible; no pitting of the low-carbon sheet steel occurred!

Write for free Bulletin 1381 with handy selection chart showing characteristics of and uses for typical Rodine Pickling Acid Inhibitors and Bulletin 1448 on Amchem Cuprodine, the simple non-electrolytic immersion process for producing bright, adherent copper coatings on carbon and stainless steels.



**AMCHEM  
RODINE**

Amchem Rodine is another chemical development of **Amchem Products, Inc., Ambler 32, Pa.** • Formerly American Chemical Paint Company  
 Detroit, Mich. • St. Joseph, Mo. • Niles, Calif. • Windsor, Ont. / Amchem, Rodine and Cuprodine are registered trademarks of Amchem Products, Inc.



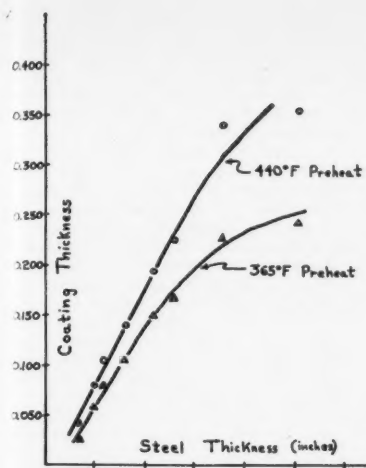


Figure 1—Dip coating of sheet steel immersed for 10 minutes.

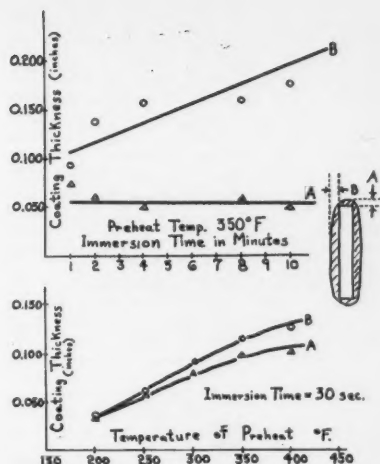


Figure 2—Coating thicknesses on a 3/16 by 1-3/16 inch floor grating bar as affected by pre-heat temperature and immersion time.

## Recent Developments in Applying Polyvinylchloride Plastisols\*

POLYVINYLCHLORIDE plastisols were first used industrially in the electroplating industry to protect plating racks from acids and chemicals and later were used to protect fume exhaust ducts, hoods, blowers and tanks.

Use of chemically resistant plastisols include steel pickling, uranium ore processing, manufacture of triple superphosphate, in rayon related industries, heavy chemical and titanium chloride production, electroplating, electrochemical, pulp and paper industries and metals refining.

Plastisols are applied by dip coating, simple and slush moulding, rotational casting and spray coating.

### Dip Coating

Dip coating is the application method generally used for protecting fume exhaust ducts, hoods, blowers, floor grating, handrails and structural members. Metal parts are preheated to predetermined temperatures and dipped while hot. The part is immersed carefully to avoid air entrapment and withdrawn slowly. Gelling of the coating occurs simultaneously. The part also can be allowed to cool in the vat until all sensible heat is dissipated in gelling the plastisol. The excess plastisol must be allowed to drain off—a time consuming process. Coated parts from both

### Abstract

Discusses industrial application of polyvinylchloride plastisols by dip coating, simple and slush moulding, rotational casting and spray coating. Also presents recent developments such as controlled thicknesses on large steel panels and rigid plastisols with components reactive with either catalysts or hardeners to give chemical resistance, low water absorption and heat stability.

5.4.5

types of dipping are heated to approximately 375 F to produce fluxing of resin and plasticizer.

The amount of build-up for a given plastisol is a function of the available heat which depends on the mass of metal and the preheat temperature. Figure 1 indicates the coating thickness possible with a single dip when panels of different gauge are preheated to 350 F and 440 F. The samples were immersed until the coating became an insulator and no further gelling was possible because of the temperature gradient.

In dip coating, even after several hours of operation, the plastisol does not heat perceptibly because of the insulation effect of the coating. Figure 2 illustrates the pick up on a 3/16 by 1 3/16 floor grating bar.

Dip coating is used also to prepare large sheets for field lining by dipping unprimed panels. Sheets prepared in this manner are stripped off the unprimed steel panels after curing. A multiple cement system similar to that for calendered sheets is used to apply the lining to the vessel. Joints are filled with plastisol and sealed with a hot air gun and welding strips. Gasket material ranging in durometer from 15 to 75 is prepared in this manner.



Figure 3—New application method of applying coatings to large plates which are shaped, welded and the uncoated weld then coated with the plastisol.

Sleeves, boots, expansion joints, valve and pillow block shrouds and gloves are made by dip coating ceramic, cast aluminum, sheet metal or electroformed forms and removing the part after curing.

If flow characteristics are controlled, such items as wire baskets can be dipped cold and withdrawn slowly for a 0.030-inch coating per dip. This method is used for racks and baskets in automatic dishwashers.

### Simple Moulds

Another widely used plastisol application method is to cast items in simple moulds at atmospheric pressure. The durometer can be varied from 10 for printing rolls to over 100 for special rigid PVC fitting lining. Mould release agents can be incorporated in the plastisol or applied to the mould surface.

### Slush Moulding

A third method for making plastisol parts is slush moulding. An inexpensive (Continued on Page 108)

\* Extracted from a paper titled "Recent Progress in Industrial Uses of Plastisols" by J. Watson Pedlow, Quelcor, Inc., Chester, Pa., presented at a meeting of the 15th Annual Conference, National Association of Corrosion Engineers, March 16-20, 1959, Chicago, Illinois.

## Recent Developments—

(Continued From Page 107)

electroformed mould is filled with plastisol and heated to start gelling; the excess is poured out and fusion completed by additional heating. Gloves, boots and shrouds can be made in this manner.

### Rotational Casting

Rotational casting of parts gives higher production rates than the other application methods. Inexpensive moulds are used, and the exact plastisol charge is added to the mould before closing. Uniform coating thickness is achieved by rotating the mould on two axes during heating to promote gelling and fusion. Spherical floats and automotive air ducting are made in this manner.

For parts too large for dipping or where economy requires coating application to one surface only, plastisols are sprayed in multiple coats of approximately 0.040 to 0.050 inch per coat. Because of the high yield values, impingement of the sprayed plastisol produces a noticeable orange peel effect. Often, orange peel can be eliminated by using newly developed airless spraying equipment. The spray method is highly effective for lining large tanks because a seamless coating can be obtained. Thicknesses of  $\frac{3}{32}$ ,  $\frac{1}{8}$ ,  $\frac{3}{16}$  inch or greater can be attained.

### More Recent Developments

More recent developments in the plastisol field will open up more opportunities for the use of this material. An outstanding development has been the

application of a controlled thickness of plastisol on large steel plates. Plastisol for this application is a special chemical resistant formulation with low permeability which is heat-fused to the metal. The adhesive system builds resistance to stripping above 75 pounds per inch as compared to a 25-pound maximum possible with conventional sheet lining systems. There is no air or solvent entrapment between the lining material and metal as is in sheet linings. Ninety percent of the lining work is performed in the shop under controlled conditions.

This new method consists of applying coatings of thicknesses of  $\frac{1}{16}$  to  $\frac{3}{16}$  inch or heavier to large plates. A 2 to 3-inch unprimed and unadhered border permits folding back the lining so the steel can be welded. After welding and cleaning, the unadhered flap is attached to the steel by a special adhesive system. The butt joint is filled with the same plastisol and infrared cured. For added strength at the joint, a sealing cover strip can be heat-fused in place. This procedure is shown in Figure 3.

Tank shells can be rolled and welded in the shop; tank bottoms can be cut to size, shaped and welded into larger sections in the shop. Dished heads can be clad prior to welding to the cylinder. Fittings can be precoated and provided with an integral spool type lining. The lining is then folded back into the flange nipple; the nipple is welded in place and the lining and flange then pulled out of the nipple and cemented to the inside lining on the tank. If an extra outlet is required, holes can be flame cut through the steel and lining, the nipple welded in place and the area covered with the lining on the interior of the nipple.

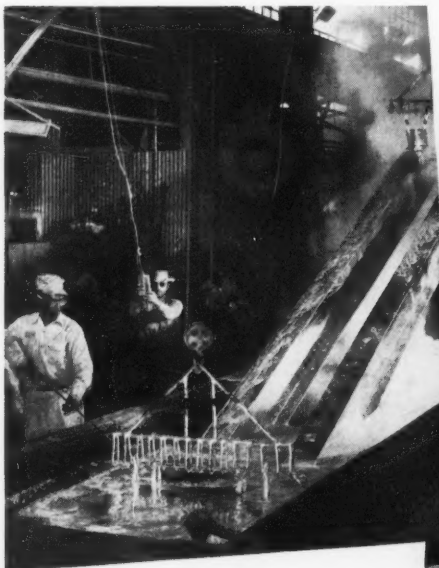
About 30 percent fewer seams are required by this technique. This method also lends itself to fabrication of pre-clad plates which can be assembled into electroplating tanks and other smaller vessels on a do-it-yourself basis. Techniques for joining these pre-clad tank walls and bottoms have been developed in which special epoxy joints backed with light weight angles have been used. Several vessels fabricated in this manner are now undergoing tests.

Variations in this technique permit the use of a rigid plastisol in place of the flexible type or a sandwich construction using the rigid over flexible. The rigid plastisol can be applied by overdipping or spraying. This relatively simple method can be undertaken by companies fabricating vessels for the chemical process industry.

Another recent development is a rigid plastisol whose plasticizer components are reactive with either catalysts or hardeners to give products which have outstanding chemical resistance, extremely low water absorption and excellent heat stability. PVC temperature resistance has been attained above 180 F.

Parts can be dip-coated by conventional methods or spray coated with an airless spray system without the use of volatiles. Physical properties of rigid PVC sheets and rigid plastisols are given in Table 1.

As the heat distortion temperature is increased, the impact strength suffers. This factor is not serious as far as the lining is concerned if the lining is backed by steel. Where high impact strength is required for self-supporting members, this factor can be overcome by the use of fibre glass in the form of flock or fabric. High heat distortion type plastisol will permit PVC applications which have been ruled out for temperature reasons.



ECONOMICAL - VERSATILE - COMPLETE

**HOT-DIP GALVANIZING**  
is your  
best  
**PROTECTION AGAINST RUST**

**Economical Protection:** Low initial cost, and long-life protection make hot-dip galvanizing the most economical rust preventative you can buy. Zinc coatings eliminate many maintenance costs; give additional life to vital structures.

**Versatile Protection:** The number of items that can be protected by galvanizing continually grows. The hot-dip method protects all types of iron and steel. Large or small, and under all conditions.

**Complete Protection:** Hot-dip galvanizing protects your structures and/or equipment completely. Complex shapes, inside surfaces, and all hard-to-reach areas receive the same uniform, long-life protective zinc coating.

Consult with Nowery J. Smith's corrosion prevention specialists during the design phase of your project. Get better protection from corrosion at less cost.

Think Nowery J. Smith Co. for Hot-Dip Galvanizing • Metallizing • Pickling Sandblasting • Painting • Plastic Applications • Vessel Lining.

LARGEST HOT-DIP GALVANIZERS IN THE SOUTHWEST

**NOWERY J. SMITH CO.**

8000 HEMPSTEAD HIGHWAY • P. O. BOX 7398  
HOUSTON 8, TEXAS • UNDERWOOD 9-1425

ONE OF THE SMITH INDUSTRIES—



AS THE isomerization process used in refineries today involves the influence of hydrochloric acid at high pressures and temperatures up to the acid's boiling point, the process vessels used require a very high resistance to corrosion. A highly corrosive resistant nickel alloy, can provide the needed protection.

This alloy is a fairly expensive substance which requires considerable metal-working skill to fabricate. Ways must be sought to retain the alloy's advantages while holding fabrication costs to a minimum. With increasing demands for high octane gasolines for both civilian and defense purposes, the need for new methods of working with this alloy is increasing also.

An excellent example of efficient use of this nickel alloy as a lining for a pressure vessel is a 13,000-pound vessel manufactured for a refinery in Mexico. A procedure of applied liners, seam-sealing and overlay strips to a base of relatively inexpensive carbon steel was used. Cost of the vessel was approximately \$22,000.

half way between that of the lined vessel and the solid alloy vessel.

When fabrication of a pressure vessel for the Mexican refinery was considered the most economical approach to the corrosion problem was decided to be construction of a carbon steel vessel completely lined with nickel alloy. Constructed under the rules of the ASME Boiler and Pressure Vessel Code, Section VIII, for corrosive service at 350 psi and 450 F., the vessel is expected to give many years of satisfactory service.

#### Design and Fabrication Procedure

Preliminary steps in the construction process were those of cutting to size and forming all carbon steel parts. The lining material (nickel 61 percent, molybdenum 26 to 30 percent, iron 4 to 7 percent, cobalt 2.50 percent, chromium 1.00 percent, manganese 1.00 percent, silicon 1.00 percent and carbon 0.05 percent) also was cut into plates and formed whenever this could be done preceding actual fabrication. The shell section was

inert-gas metal arc-welding process with  $\frac{3}{32}$ -inch diameter bare wire as filler metal. Channels under the overlay strips were continuous throughout the vessel to permit testing of the overlays for leakage.

#### Testing

Testing of the vessel's lining was accomplished by introducing pressure behind the overlay strips.

Weep holes  $\frac{1}{16}$ -inch in diameter were drilled behind all pieces of overlay stripping. A similar hole was drilled behind each piece of liner plate. Pipe couplings were then welded over each weep hole. Air at 15 psig pressure was introduced through an overlay strip weep hole at one end of the vessel. All other weep holes under the over-lay strips were checked for air flow and then plugged. This procedure made certain that air was flowing through the space under all overlay strips.

With all weep holes plugged, inside seams were checked for leakage by

## Nickel Alloy Lining Cuts Costs In a Refinery Isomerization Unit\*

If this same vessel had been constructed of solid corrosion resistant nickel alloy, the cost would have been over twice this amount.

Another approach to the problem might have been the use of integrally clad metal. This process, still under development, is being done successfully with shell and head material but requires that the supplier perform the fabrication and joining functions by his own manufacturing procedures. Cost of the completed vessel would be approximately

\* Revision of a paper titled "Hastelloy Alloy Lining Cuts Isomerization Unit Costs" submitted by John F. De Lorenzo, Manning & Lewis Engineering Co., Newark, N. J., October 6, 1958.

planned to be lined with 8 courses of  $\frac{3}{4}$ -inch thickness by 7-inch wide alloy sheet. Each course would contain 4 pieces 7 by 46 $\frac{1}{2}$ -inch long, laid in transversely one at a time.

Prior to welding each liner piece, the shell area to be covered was sandblasted. Strips were kept tightly against the shell by a hydraulic jack and a hard wooden form. This gave greater ease in welding and also helped dissipate the heat generated by welding. No preheating was used because the alloy is hot-short at elevated temperatures. Welding was done by the metal arc process in the down-hand position with coated stainless steel 310 electrodes for the carbon steel to alloy welds. Normal current for the  $\frac{3}{32}$ -inch electrode used is 90 amps at 25 volts. To keep the heat effect on the alloy to a minimum, the electrode was directed almost entirely on the steel with the edge of the arc making contact with the liner. A single bead was used and laid in at the most constant speed possible for non-automatic welding. To avoid locked-in stresses, one short and one long edge of the liner were welded and allowed to cool prior to welding the other two edges.

Procedure for lining the elliptical head was more complicated. Positioned concave side up, the elliptical head was surmounted by a pipe tripod with tripod legs clamped to the straight flange. The apex served as the pivot point for the hydraulic jack that exerted pressure on the hard wooden forms used to position and form the various liner pieces. The welding techniques were identical to that used on the shell.

Spaces between adjacent liner sections were covered by 2-inch wide strips of 14 gauge nickel alloy. These overlay strips were held in position in the same manner as the liner pieces and were welded to the alloy lining using the

#### Abstract

Describes a corrosion resistant nickel alloy lining used in an isomerization unit fabricated for a refinery in Mexico. Design, fabrication procedure and tests conducted on the unit are discussed briefly. 5.4.3

means of preliminary soap and water tests, followed by highly sensitive tests using Freon and a halogen leak detector. These showed all seams free from leakage. The plugs were then removed, and an internal halogen test was performed with all external seams and weep holes being probed.

After removing the couplings, weep holes in the bottom head were plugged welded. The bottom head jacket was installed, and the entire unit subjected to final hydrostatic testing. This was done at 525 psig in the shell and 115 psig in the jacket.

#### Technical Topics Included in Index

Technical Topics will be included in CORROSION's annual index. The Topics will be included in the alphabetical subject and author index.

Persons who customarily extract Technical Section pages from each issue for binding are reminded that the Technical Topics pages should be extracted also for a more complete reference to technical information published in CORROSION.

### NOW You Can Get PHOTOFACSIMILE COPIES

of  
NACE Literature  
Previously Unavailable  
Because of Exhausted  
Stocks

**COST:**  
**15c Each Page**

Remittance in Advance on  
Orders Less than \$5.00  
Minimum Charge 50c

In Placing Orders Give Complete Reference Data.  
Copies of NACE Material Only Covered by This Offer

Send Order and Remittance to:  
**NATIONAL ASSOCIATION  
OF  
CORROSION ENGINEERS**

1061 H & M BLDG. HOUSTON 2, TEXAS



NOW You Can Get  
**PHOTOFACSIMILE  
COPIES**

of  
NACE Literature  
Previously Unavailable  
Because of Exhausted  
Stocks

•  
**COST:**  
**15c Each Page**

Remittance in Advance on  
Orders Less than \$5.00  
Minimum Charge 50c

*In Placing Orders Give Complete Reference Data.  
Copies of NACE Material Only Covered by This Offer*

Send Order and Remittance to:  
**NATIONAL ASSOCIATION  
OF  
CORROSION ENGINEERS**

1061 M & M BLDG.

HOUSTON 2, TEXAS

Vol. 15

3. CHAR  
CORR

3.2 For

3.7 Me

3.8 Mi

5. PREVI

5.3 Me

5.4 Ne

5.5 Oi

5.9 Su

6. MAT

6.2 Fe

6.3 Ne

an

8. INDU

8.4 G

8.5 G

8.8 G

3.

3.2

3.2.2, 6

Etch

nese.)

Fujita

Osaka

Etch

by ele

nates

by et

planes

the b

form

becom

in siz

metric

guish

nucle

acco

solute

leaves

cleus-

3.2.2, 6

Cor

Steels

Italian

1/2, 5-1

Inte

main

stainl

chrom

tion,

much

contac

struct

strate

Sensit

ferent

discu

INCO



# CORROSION ABSTRACTS

## INDEX TO CORROSION ABSTRACTS

Vol. 15 August, 1959 No. 8

### 3. CHARACTERISTIC

#### CORROSION PHENOMENA

- 3.2 Forms .....111  
3.7 Metallurgical Effects .....111  
3.8 Miscellaneous Principles .....115

### 5. PREVENTIVE MEASURES

- 5.3 Metallic Coatings .....116  
5.4 Non-Metallic Coatings and Paints .....116  
5.5 Oil and Grease Coatings .....117  
5.9 Surface Treatment .....118

### 6. MATERIALS OF CONSTRUCTION

- 6.2 Ferrous Metals and Alloys .....118  
6.3 Non-Ferrous Metals  
and Alloys—Heavy .....119

### 8. INDUSTRIES

- 8.4 Group 4 .....120  
8.5 Group 5 .....126  
8.8 Group 8 .....126

### 3. CHARACTERISTIC CORROSION PHENOMENA

#### 3.2 Forms

##### 3.2.2, 6.4.2, 2.3.6

Etch Pits in Aluminum. (In Japanese.) Zenji Nishiyama and Hiroshi Fujita. Inst. Sci. and Ind. Res., Memoirs Osaka University, 15, 113-128 (1958).

Etch pits in aluminum were observed by electron microscope. The pit originates at an etching nucleus and grows by etching with three composite (100) planes intersecting at the nucleus. At the beginning of formation it has the form of a circular cavity, but when it becomes larger than several hundred Å in size it is angular so that the geometrical type of the pit can be distinguished. In most cases the origin of the nucleus seems to be the edge dislocation accompanied with the atmosphere of solute atoms and the etching progress leaves fine contour lines around the nucleus.—ALL. 16870

##### 3.2.2, 6.2.5

Corrosion Resistance of Stainless Steels. Intergranular Corrosion. (In Italian.) L'Acciaio Inossidabile, 25, No. 1/2, 5-16 (1958) Jan-April.

Intergranular corrosion constitutes main negative characteristic of austenitic stainless steels of chromium-nickel and chromium-nickel-manganese composition. Intergranular corrosion is not so much a function of fluid which comes in contact with stainless steel as it is of structure of steel itself. This is demonstrated when the steels are sensitized. Sensitization of stainless steels and different theories of carbide formation are discussed. Photomicrographs, graphs.—INCO. 16578

##### 3.2.2, 3.7.4

High Temperature Intercrystalline Cracking. D. Kramer and E. S. Machlin. Acta Metallurgica, 6, No. 6, 454 (1958) June.

Fraction of total grain-boundary area occupied by cracks and voids was measured using C. S. Smith's method: number of times unit length of line is intercepted by grain-boundary crack or void divided by number of times line is intercepted by grain boundaries. Results yield linear relation between total crack and void area and total high temperature strain. This result is strong argument against vacancy condensation mechanisms proposed for void growth. It was shown that amount of grain-boundary sliding is proportional to amount of high temperature elongation. This relation is expected to exist for nickel. Graphs.—INCO. 16539

##### 3.2.3, 6.2.2

Texture of Iron Scale. Pt. 10. Texture of Ferrous Scale. (In Russian.) V. I. Arkharov and M. I. Simonova. Fizika Metallov i Metallovedenie, 4, No. 2, 278-290 (1957).

Oxidation conditions; measurement of crystalline lattice of ferrous oxide; X-ray photographs of ferrous oxide crystals. 8 references.—MR. 15722

##### 3.2.2, 6.3.15, 3.7.4

Delayed Failure and Hydrogen Embrittlement in Titanium. R. D. Daniels, R. J. Quigg and A. R. Troiano. Case Inst. of Technology for U. S. Wright Air Development Center, U. S. Air Force, Feb., 1958, 62 pp. Available from Office of Technical Services, U. S. Dept. of Commerce, Washington 25, D. C. (Order PB 151139).

The tendency for hydrogen induced delayed failure in an alpha-beta titanium alloy varied considerably with microstructure, according to this report. The material used was a commercial 4 aluminum-4 manganese alloy hot rolled in the alpha-beta region. As-received tensile strength was about 140,000 psi. Among many other conclusions, it was noted that a quenched structure was less susceptible to delayed failure than aged or annealed structures and that the tendency for failures was magnified in all structures by an increase in hydrogen content or an increase in strength level. Hydrogen induced failures occurred by a process of crack initiation and controlled crack growth. Delayed failures resulting from creep were encountered, even in notched specimens. At both high and low temperatures, hydrogen induced delayed failure disappeared and the time required for failure as well as the minimum stress at which failure could occur increased at elevated temperatures.—OTS. 16473

#### 3.7 Metallurgical Effects

##### 3.7.2, 6.2.2, 3.4.8

The Effect of Chromium on the Sulfide Corrosion of Its Iron Alloys. (In Russian.) A. K. Semenova and P. V. Gel'd. Kirov Ural Polytechnic Inst. J.

Phys. Chem., USSR (Zhur. Fiz. Khim.), 32, No. 5, 1087-1094 (1958) May.

The similarity of the protective action of chromium in both the oxide and the sulfide corrosion of its alloys with iron was confirmed experimentally. It is shown that in the oxidation of chromium-iron alloys by sulfur, chromium accumulates in the inner scale layer, forming the spinel  $\text{FeCr}_2\text{S}_4$ . When the alloy contains over 12% chromium, the inner layer consists predominately of the sulfide spinel, abruptly retarding the diffusion of anions and cations. This renders the alloy corrosion resistant. (auth)—NSA. 16629

##### 3.7.2, 3.7.3, 6.2.5, 3.2.2

Influence of Nickel on Intergranular Corrosion of 18% Chromium Steels. J. R. Upp, F. H. Beck and M. G. Fontana. Trans. Am. Soc. Metals, 50, 759772 (1958).

Type 304 (18-8) stainless steel is made susceptible to intergranular corrosion when heated in the temperature range of approximately 1200 to 1400 F. This heat treatment imparts resistance to intergranular corrosion for Type 430 (18% chromium) steels. Quenching from 1900 to 2000 F provides optimum resistance to Type 304 but makes Type 430 susceptible to intergranular corrosion. The major compositional difference in these steels is nickel (8%

Abstracts in This Section are selected from among those supplied to subscribers to the NACE Abstract Punch Card Service. Persons who are interested in reviewing all available abstracts should write to NACE for information on this service.

### PHOTOPRINTS and/or MICROFILM COPIES

of Technical Articles Abstracted in

### Corrosion Abstracts

May Be Obtained From

ENGINEERING SOCIETIES LIBRARY, 29 West 39th Street, New York 18, N. Y.

CARNEGIE LIBRARY OF PITTSBURGH, 4400 Forbes St., Pittsburgh 13, Pa.

NEW YORK PUBLIC LIBRARY, New York City.

U. S. DEPT. OF AGRICULTURE LIBRARY, Office of Librarian, Washington, D. C. (Special forms must be secured).

LIBRARY OF CONGRESS, Washington, D. C.

JOHN CRERAR LIBRARY, 86 East Randolph St., Chicago 1, Ill.

Persons who wish to secure copies of articles when original sources are unavailable, may apply directly to any of the above for copies. Full reference information should accompany request. The National Association of Corrosion Engineers offers no warranty of any nature concerning these sources, and publishes the names for information only.

NACE will NOT accept orders for photoprint or microfilm copies of material not published by the association.

and 0%). Alloys containing intermediate nickel compositions were cast, rolled, heat treated and tested to determine the influence of this element on corrosion behavior. It was found that the transition occurs at about 2.5 to 3% nickel. Steels with higher nickel should be heat treated like the austenitic steels and those below like the ferritic steels. An unexpected result was the good resistance to intergranular corrosion of all of these alloys when water quenched from 1400 F. (auth) —NSA. 16693

### 3.7.2, 6.4.2

**Effect of Antimony Additions on Aluminium Alloys.** W. Thury. Metall, 11, No. 3, 190-192 (1957).

Antimony additions to magnesium-containing aluminum alloys precipitate most of the magnesium in the form of primary  $Mg_3Sb_2$  crystals which form a pasty and easily separable sludge. However, approximately 0.4% antimony is retained in the melt, which after solidification appears as finely dispersed  $Mg_3Sb_2$  crystals; these, if the alloy contains silicon, are less corrosion-resistant than magnesium silicide, the formation of which is suppressed by the antimony addition. Although, technically this procedure might be of use in working-up scrap magnesium-containing alloys, the high cost of the antimony makes it uneconomic unless a cheap and simple method could be devised for recovering the antimony from the sludge. Increasing additions (up to 1%) of antimony to Silumin and Silumin- $\beta$  alloys increase their ductility, but reduce and finally suppress age-hardening and, therefore, cannot be recommended. —MA. 16389

### 3.7.2, 6.4.2, 2.2.3, 4.6.11

**The Effect of Manganese and Chromium on the Characteristics of Aluminium-5% Magnesium Wrought Alloys.** (Report 2), Corrosion Resistivity (Part 1), Corrosion in Seawater with Sample of 2.4 mm Thickness. Rihei Kawachi. Light Metals Japan, No. 29, 14-23 (1958) March.

In order to confirm the effect of manganese and chromium in aluminum-3~5% alloys and of iron, silicon, copper, titanium, in aluminum-4~4.5% magnesium-0.5% manganese-0.2% chromium alloy on the corrosion resistivity, changes of tensile properties during immersion of the samples in the seawater for up to 12 months were tested. It is seen that, in general, aluminum-magnesium binary alloys are the best and the addition of manganese, chromium, iron or copper decreases corrosion resistivity, whereas the effects of silicon, zinc and titanium are small. (auth).—ALL. 16069

### 3.7.2, 3.5.8, 6.4.2

**The Relationship Between Magnesium Content and Stress-Corrosion Susceptibility of Aluminium-Magnesium Alloys.** W. J. Vance. J. Applied Chem., 8, 18-23 (1958) Jan.

The susceptibility to stress-corrosion cracking of commercial purity aluminum-3.5% magnesium and aluminum-2.25% magnesium alloys was determined by corroding strain-aged 16 s.w.g. wire specimens by intermittent immersion in buffered 3% sodium chloride solution. Susceptibility values were 18.4 and 0% respectively. Results suggest that susceptibility is proportional to alloying magnesium content.—BTR. 15502

### 3.7.2, 3.8.3, 6.4.2

**Some Comments on the Anodic Oxidation of Aluminium Alloys Containing Copper.** J. Herenguel and P. Lelong. Metal Finishing J., 4, No. 37, 20-23 (1958) Jan.

The addition of copper to aluminum gives rise to a certain number of special features in anodic oxidation. When the copper is not wholly in solid solution (as-cast structure or precipitation treated) local attack is inevitable. In solid solution, copper acts in the reverse way to magnesium, by hindering the mechanism of anodic oxidation and reducing its speed. It appears as if the presence of copper restrains the progress of the electrolysis and causes an actual blockage. The early re-attack at the electrolyte-film interface for a given temperature or current density may result from an increased electrical resistance of the film (thus causing a rise in temperature throughout the film thickness). The rapid attack on AlCu on the one hand and the early onset of attack on the oxide film surface on the other must not cause the fact to be overlooked that the presence of copper slows up the process of anodic oxidation of the solid solution itself. The resistance effect produced by the growth of the oxide film is supplemented by a specific effect arising from the presence of an insoluble copper compound. It would be particularly desirable to be able to dissolve such compounds during electrolysis which would make possible the treatment of aluminum-copper solid solutions under conditions approximating to those of Al itself, i.e., with the same practical possibilities. (auth)—ALL. 15619

### 3.7.2, 6.2.5, 3.7.3

**Effect of Nickel in High-Carbon High-Chromium Die Steel.** S. Koshiba and S. Nagashima. Paper before Iron and Steel Inst. Japan, April, 1957. J. Iron and Steel Inst. Japan, 44, No. 1, 43-46 (1958) Jan.

Experiment was conducted with the high-carbon, high chromium die steel containing nickel to check the effect of nickel on the mechanical properties of steel after heat treatment. Addition of about 0.5% nickel to the die steel would give a favorable effect to the distortion characteristic of the steel in the heat treatment.—INCO. 16826

### 3.7.2, 6.2.2

**The Effect of Vanadium on Some Characteristics of Cast Iron.** G. Meckler. Paper before Ausschuss für Guss, December, 1956. Stahl und Eisen, 78, 900-906 (1958) June 26.

Study of effects of additions of vanadium (up to about 1%) on nickel, nickel-chromium, nickel-molybdenum, molybdenum and nickel-chromium-molybdenum alloy cast irons. Influence on hardness and tensile strength (up to 450 C) in as-cast and annealed conditions is discussed. Investigation was made of effects of alloy additions of nickel (1-2.8%), chromium (0.6-0.9%) and molybdenum (0.3-0.7%). Influence of vanadium on grey cast iron (about 1.15% silicon), with reference to roll applications is included.—INCO. 16970

### 3.7.2, 3.7.3, 6.2.4

**Effect of Some Alloying Elements on Weldability of Low Alloy Structural Steels.** (In Japanese.) H. Suzuki and H. Tamura. Paper before Iron and Steel

## You Can Find the Article

Add 65c per package to the prices given for Book Post Registry to all addresses outside the United States, Canada and Mexico.



Per Copy  
**\$250**

## Easily

27 pages, 8½ x 11, paper. Alphabetical subject, author and chronological index of 629 articles by 1056 authors published in the decade 1945-54. A real time saver for the corrosion worker.

1945-54

## 10-YEAR INDEX to CORROSION

**NATIONAL ASSOCIATION of CORROSION ENGINEERS**

Phone Capitol 4-6108

1061 M & M Bldg.

Houston 2, Texas



Inst. Japan, April, 1957. J. Iron and Steel Inst. Japan, 44, No. 2, 129-136 (1958) Feb.

Nickel, chromium or molybdenum was added to a steel containing 0.14% carbon (0.18% for molybdenum series only), 1.10% manganese and 0.35% silicon. Eighteen steel heats were melted and cast into small ingots each weighing about 3.5kg and then rolled to bars with diameter of 16 mm. Tensile test, V-Charpy test and simplified weld maximum hardness test were conducted with taper bar specimens after the heat treatment comprising normalizing and water quenching followed by tempering at 650 C. In the quenched and tempered condition, an addition of nickel resulted a remarkable increase of tensile strength of the steel, while its yield strength was but slightly improved by it. In the quenched and tempered condition, an addition of chromium gave a remarkable effect on the steel by improving the tensile strength, although the reduction of area and elongation were somewhat decreased by it. An addition of molybdenum resulted a remarkable increase in tensile strength and yield strength of the steel as it was normalized, quenched and tempered. The transition temperature was lowered by an addition of nickel up to about 1%, but it was raised slightly when the addition of nickel was over 1%. An addition of chromium as well as molybdenum gave a considerable effect to the steel by raising the transition point. Generally the toughness of a notched specimen was improved when it was quenched and tempered rather than normalized. The maximum hardness of an as-welded portion of the specimen was not increased significantly by an addition of nickel in less than 1%, however, it was increased remarkably by an addition of chromium and molybdenum. Recommended ranges in mechanical strength of steel for having a satisfactory weldability are given.—INCO. 16971

**3.7.3 An Evaluation of Ultrasonic Solder Joints.** D. W. Grobecker and J. B. Duran. U. S. Atomic Energy Commission Pubn., SCTM-163-58(16), April 23, 1958, 12 pp. Available from Office of Technical Services, Washington, D. C.

A comparison is made between joints soldered by ultrasonic methods and specimens soldered by the usual hot iron and flux technique. Test samples of mild steel, copper, aluminum and stainless steel joined with tin-lead and tin-zinc alloys are compared. Ultrasonic soldering techniques appear to offer an advantage in joining aluminum alloys with tin-zinc solder and copper alloys with tin-lead solder without the utilization of a fluxing addition. However, the mechanical characteristics of tin-zinc soldered joints are degraded by a humidity exposure. auth—NSA. 16811

**3.7.3 Salt Bath Brazing.** L. B. Rosseau. Paper before Western Metal Congress (Am. Soc. Metals), Symposium on Brazing and Sintering, Los Angeles, 1957. Ind. Heating, 25, No. 7, 1325-1326, 1328, 1330, 1334, 1346 (1958) July.

Describes general characteristics, advantages and applications of salt bath or dip brazing, with special attention to brazing of aluminum assemblies. In air frame industry, honeycomb structures of 17-7 PH are brazed with alloy with melting point of 1775 F, and assembly is sealed in tight envelopment to pre-

vent contact with salt; salt serves only as heat transfer medium.—INCO. 16884

**3.7.3 Low Crack Sensitivity of Steel Joint by Carbon Dioxide-Oxygen Arc Welding.** H. Sekiguchi and I. Masumoto. Welding J., 37, No. 7, 326s-336s (1958) July.

In Japan, new gas-shielded metal-arc welding process has been applied automatically and semiautomatically. Mixture of carbon dioxide and oxygen is supplied around arc and molten pool and bare steel wire containing suitable quantities of deoxidizers is used as metal electrode. Outline of process is given. Frequency of fish-eye occurrence, hydrogen content and crack sensitivity of steel joints prepared by various processes are compared. Hydrogen content and crack sensitivity of welds made by carbon dioxide-oxygen process were lower than those of welds made by other processes. Weldability and cracking tests were carried out on high-tensile low-alloy steels (0.84 nickel) and on 2.80 nickel-1.23 chromium-0.27 molybdenum steel plate. Tables, graphs, macro- and microphotographs.—INCO. 16857

**3.7.3 Welding Copper-Base Alloy Tubes.** J. F. Sebald and L. H. Hawthorne. Paper before Am. Soc. Mechanical Engrs., Annual Mtg., Panel on Welding of Nonferrous Tubes to Tube Sheets. New York, 1957. Power, 102, Nos. 3, 4, 6; 94-97, 196, 198, 200; 92-95, 194, 196, 198, 202, 204; 108-111, 208, 212, 214, 216, 218 (1958) March, April, June.

Outlines test program and summarizes results in effort to answer questions on distortion from welding, relation between distortion from welding, relation between distortion, tube-sheet thickness and materials welded, resistance to repetitive stress and potential resistance to corrosion. Data presented help to resolve design details needed to produce good weld joint and minimize risk on large surface condensers. Tube materials selected for study are those most commonly used in steam condensers: arsenical copper, admiralty and aluminum brass. Tube-sheet materials include naval brass and copper-silicon.

Leak-tightness and pressure-strength tests are reported for all those materials in various combinations. Tube-sheet distortion tests and corrosive investigations cover combinations of admiralty and aluminum brass tubes with naval brass and copper-silicon tube sheets. Data are presented on resistance to cyclic stress conditions in simulated heat-exchanger construction for admiralty and copper-silicon tube sheet designs. All welding, manual and machine, was made by gas-shielded tungsten arc process without using filler metal. Tables, diagrams.—INCO. 16903

**3.7.3 Application Aspects of Wire Mesh Welding.** S. Fisher. Paper before Wire Assoc., Buffalo Regional Mtg., May 1, 1958. Wire and Wire Products, 33, No. 7, 757-762, 804-807 (1958) July.

Discusses various facets of application that must be considered in improving and revamping wire mesh welding machines. Basic factors such as material weldability, weld strength, machine electrical characteristics, general machine characteristics and wire handling, as related to fully automated line, are covered. Weldability is discussed for mild steel, high carbon steel, stainless steel, low alloy steels and aluminum. Chart shows

## COKE BREEZE

### Backfill for Anodes

Ideally suited for use with anodes. Has a high carbon content and comes in sizes of 1/8-inch x 0 to 3/4 x 1/2 inch. In bulk or sacks. Prices on other sizes on request.

### National Carbon Anodes

### Magnesium Anodes

### Good-All Rectifiers

## WHOLESALE COKE COMPANY

PHONE GARDENDALE, ALA.  
HEMlock 6-3603

P. O. Box 94

Mt. Olive, Ala.

## CUT PRICE

means

## CUT QUALITY

Cut quality follows cut price as invariably as night follows day. When a price cutter gives you an appealing bargain bid—beware of the unappealing long range consequences.

It's all a matter of common sense. The price cutter is in business to make a profit. The amount he cuts from his bid can only come from the quality materials and workmanship you expect

and deserve from a coating and wrapping job. Cutting corners on quality is the surest way of cutting down on the life of the pipe underground.

At Mayes Bros. we don't sell cut rate prices. We sell *permanence in pipe*. We've specialized in putting permanence in pipe for the past 30 years. And we'll continue doing it as long as our name is on the door.

1150  
McCarthy  
Drive

**MAYES BROS.**  
HOUSTON, TEXAS

Tel.  
ORchard  
2-7566

data for crossed wire welding of low carbon steel wire.—INCO. 16938

### 3.7.3, 8.4.5

**Development of Methods for End Capping PWR Fuel Elements.** Julius J. Vagi and David C. Martin. Battelle Memorial Inst. U. S. Atomic Energy Commission Pubn., BM1-1061, December 28, 1955 (Declassified April 2, 1957), 46 pp. Available from Office of Technical Services, Washington, D. C.

Exploratory tests performed during the first phase of this investigation indicated that the uranium-12 wt.% molybdenum cored fuel rod for PWR might be end capped by resistance-upset welding. Studies of welding methods were continued to develop procedures which would improve the integrity of resistance-upset-welded end-closure bonds. A medium-capacity spot-welding machine was utilized for resistance-upset welding recessed joints under vacuum; glass-lined steel backups were

used to prevent fuel upset. Visual examination of fractured joints and metallographic examinations of sections indicated that fuel rod-to-cap bonds were good. Corrosion testing, chemical analyses and detailed metallographic examination were used in further evaluation of the clad-to-cap bond to determine the consistency in quality of a large number of samples. Attempts to relate failures in corrosion tests with defects indicated by non-destructive tests generally were not successful. Only in cases of gross defects that were indicated by radiographs was any correlation made. A brief study of flash welding was made to determine if it could be used to obtain good clad-to-cap bonds. The results obtained did not justify extensive development. A few arc-welding tests were made to determine if fusion welds could be used to seal the resistance butt welds. (auth)—NSA. 16418

### 3.7.3, 3.5.9, 1.3

**On the Mechanism of Hot Cracking of Welds.** V. A. Toropov. Metalloved. I Obrabotka Metallov, No. 6, 54-58 (1957) June. Translation available from Henry Brucher, Technical Translations, P. O. Box 157, Altadena, California.

Critical literature review. Author's study of dependence of resistance of weld metal to hot cracking upon temperature and nature of solidification of the constituents making up the intergranular substance; limitations to this relationship. Study of certain ternary alloys having a eutectic, as examples. Possibility of improving the resistance to weld hot cracking by changing the relative quantities of intergranular constituents or by introducing new ones. Suggestions for future studies. 2 figures.—HB. 16387

### 3.7.3

**Metallurgy of the Welding of Certain Austenitic Heat- and Corrosion-Resistant Alloys.** A. H. Waterfield & R. P. Culbertson. Paper before Intern. Inst. Welding, 1st Annual Mtg., Essen, Germany, July 1, 1957. Welding J., 36, No. 8, 360s-365s (1957) August.

Corrosion-resistant alloys (nickel-molybdenum, nickel-molybdenum-chromium, and nickel-molybdenum-chromium-iron) and heat-resistant alloys (iron-chromium-nickel-cobalt known as N-155, cobalt-tungsten-nickel-chromium and nickel-chromium-molybdenum-iron) are considered. Their development and uses are touched upon. After brief description of methods of preparation for welding, metallurgical properties of each alloy are considered in light of their effect on welding techniques necessary. Fabrication methods for the two types are discussed in connection with service conditions. Graphs, photo-micrographs.—INCO. 16367

### 3.7.3

**Further Tests on the Strength of Bonded Metal Joints.** H. Winter and G. Krause. Aluminium, 33, No. 10, 669-681 (1957).

Winter and Krause review the literature on the properties of bonded joints as employed in aircraft construction. They made tests, mainly on single-lap joints, using both cold-setting and hot-setting adhesives, with and without pressure. Factors studied included surface preparation, degree of overlap, thickness of metal and of adhesive and the influence of the corrosive action of various atmospheres at different tem-

peratures. In general, hot setting under pressure gives the best results, but it is difficult to correlate results owing to the different techniques employed. 61 references.—MA. 16347

### 3.7.3, 5.9.2, 6.3.20

**Effect of Welding Atmosphere and Pickling on the Corrosion Resistance of Welded Zircaloy-2 and -3.** K. H. Koopman, W. S. Horton, A. B. Riedinger, S. A. Toftgaard and A. P. Jordan. Knolls Atomic Power Laboratory. U. S. Atomic Energy Commission Pubn., KAPL-1811, August, 1957, 29 pp.

The best corrosion resistance was obtained with the highest purity gas shielding conditions. The effect of atmosphere was more pronounced in welds made with a high heat input and integral backing than in welds made at a low heat input. Repickling leads to no improvement in corrosion resistance.—BTR. 14700

### 3.7.3, 6.4.2

**Performance of Welds in Some Aluminum Alloys.** P. B. Dickerson. Paper before Am. Welding Soc., Western Metal Congress, Los Angeles, March 27, 1957. Welding J., 37, No. 2, 107-113 (1958) Feb.

Because of recent developments in inert-gas shielded arc-welding methods additional aluminum alloys can now be welded satisfactorily and additional filler materials have come into use. Increased tensile properties with increased weld ductility are obtained. Paper covers strength and ductility of butt welds in various aluminum alloys, longitudinal and transverse shear strengths of fillet welds, effect of temperatures from -400 to +700 F upon tensile properties, and resistance to corrosion of several of the high-strength weldable alloys. Improvement in fabrication of aluminum alloys due to newly developed consumable-electrode and tungsten-electrode inert-gas cutting processes is discussed. Graphs.—INCO. 15459

### 3.7.3, 6.3.6

**Filler Metals for Joining.** O. T. Barnett. Illinois Institute of Technology. Welding Engr., 43, No. 1, 56, 59-62 (1958) Jan.; disc., *ibid.*, No. 3, 18 (1958) March.

Copper filler metals join copper base materials to each other or to such dissimilar metals as steel and cast iron. Other uses include surfacing applications for corrosion resistance, for wear resistance or for bearings. Recent specifications covering copper and copper alloy filler metals intended for welding are given. Analyses of copper welding electrodes and rods include nickel containing copper-nickel, manganese-bronze, low fuming bronze and nickel bronze. Copper-nickel filler rods are commonly selected to join copper-nickel base metals because of exceptionally good resistance to salt water corrosion. Tables, photos.—INCO. 15440

### 3.7.3, 6.4.4

**The Arc Welding of Wrought Magnesium-Thorium Alloys.** L. F. Lockwood and Paul Klain. Welding J. Supplement, 37, No. 6, 255s-264s (1958) June.

Presents the results of welding evaluation tests on the recently developed, wrought, magnesium-base, thorium-containing alloys, HK31A sheet (magnesium-3.3% thorium-0.7% zirconium), HM21XA-T8 sheet (magnesium-2.0%, thorium-0.6% manganese) HM31XA extrusions (magnesium-3.0% thorium-



## TECHNICAL REPORTS

### on SULFIDE CORROSION in the PETROLEUM INDUSTRY

**T-5B-2 Effect of Sulfide Scales on Catalytic Reforming and Cracking Units. Part 1—Metallographic Examination of Samples From a Catalytic Reforming Unit. Part 2—Intergranular Corrosion of 18-8 Cr-Ni Steel as a Result of Hydrolysis of Iron Sulfide Scale. A Contribution to the Work of NACE Task Group T-5B-2 on Sulfide Corrosion at High Pressures and Temperatures in the Petroleum Industry. Per Copy \$3.50.**

**T-5B-2 Collection and Correlation of High Temperature Hydrogen Sulfide Corrosion Data—A Contribution to the Work of NACE Task Group T-5B-2 on Sulfide Corrosion at High Temperatures and Pressures in the Petroleum Industry: From M. W. Kellogg Co., New York by G. Sorell and W. B. Hoyt. Pub. 56-7. Per Copy \$1.50.**

**T-5B-2 High Temperature Hydrogen Sulfide Corrosion in Thermoform Catalytic Reformers—A Contribution to the Work of NACE Task Group T-5B-2 on Sulfide Corrosion at High Temperatures and Pressures in the Petroleum Industry: From Socony Mobil Oil Co., Inc., Res. & Dev. Lab., Paulsboro, N. J. by E. B. Backensto, R. D. Drew, R. W. Manuel and J. W. Sjöberg. Pub. 56-8. Per Copy \$1.00.**

**T-5B-2 Effect of Hot Hydrogen Sulfide Environments on Various Metals—A Contribution to the Work of NACE Task Group T-5B-2 on Sulfide Corrosion at High Temperatures and Pressures in the Petroleum Industry: From Sinclair Res. Lab. Inc., Harvey, Ill. Pub. 57-2. Per Copy \$5.50.**

**T-5B-2 High Temperature Sulfide Corrosion in Catalytic Reforming of Light Naphthas—A Contribution to the Work of NACE Task Group T-5B-2 on Sulfide Corrosion at High Temperatures and Pressures in the Petroleum Industry: From Humble Oil & Ref. Co., Baytown, Texas. Pub. 57-3. Per Copy \$5.50.**

Remittances must accompany all orders for literature the aggregate cost of which is less than \$5. Orders of value greater than \$5 will be invoiced if requested. Send orders to National Association of Corrosion Engineers, 1061 M & M Bldg., Houston, Texas. Add 65c per package to the prices given above for Book Post Registry to all addresses outside the United States, Canada and Mexico.

## NATIONAL ASSOCIATION OF CORROSION ENGINEERS

1061 M & M Bldg. Houston 2, Texas

1.5% manganese). These alloys possessed excellent weldability and retained high strengths at elevated temperatures after welding. The strengths of the welds were equal to, or closely approached, the strengths of the base metals at elevated temperatures. The creep resistance of the alloys was not adversely affected by welding. Post-weld heat treatments did not improve the weld strength to any marked degree. The corrosion rates in 3% sodium chloride solution were not changed significantly by welding. AZ33A alloy, (magnesium-2.77 zinc-3.0 RE-0.7 zirconium) is the best rod composition for all the alloys HM31XA rod may be more advantageous in certain applications at temperatures above 600 F. The marked under-cutting tendencies during welding could be overcome by special techniques, such as pre-heating, grooved backing plates and inert-gas backing. The low level of radio-activity of thorium in these alloys is of minor consideration and is easily controlled by proper procedure. (auth.)—ALL. 15961

### 3.8 Miscellaneous Principles

#### 3.8.4, 6.2.2

**Ferrous Hydroxide Solubility, Thermal Decomposition and Role in the Corrosion of Iron.** P. D. Miller, J. J. Ward, O. M. Stewart and R. S. Peoples. *Am. Soc. Mechanical Engrs., Paper No. 57-A-184*, December, 1957, 13 pp.

Decomposition of pure ferrous hydroxide between 250 and 550 F. The major decomposition products are hydrogen and magnetite; minor constituents are alpha iron and ferric oxide. The rate of decomposition is such that it is concluded that the decomposition of ferrous hydroxide is not the rate-controlling step in the iron-water corrosion reaction at temperature above 250 F. 6 references.—MR. 16253

#### 3.8.4, 2.3.7

**Physical and Chemical Aspects of Adhesion.** S. Orhon. *Tappi*, 40, No. 9, 182-184A (1957); *Bull. Inst. Paper Chem.*, 28, No. 3, 337 (1957).

The measurement and mechanism of adhesion, including contact angles, wetting, chemical bonds (electrostatic, covalent and metallic), and Van der Waals forces (orientation or Keesom forces, induction or Debye forces, and dispersion or London forces), as well as factors influencing adhesion (such as cohesion, solubility and tensile strength of the system) are discussed. 6 references.—RPI. 16272

#### 3.8.4, 6.3.8

**Research on Dry Corrosion Oxidation of Lead Pellets.** (In French.) Haidun N. Terem. *Rev. Faculté Sci. Univ. Istanbul*, 22, 343-352 (1957) Oct.

Tiny pellets can be heated above melting point of lead without changing shape. Prior to heating, specimens were cleaned and sized with emery paper and others were further cleaned in solution of nitric acid. Oxidation of lead at any temperature obeys parabolic law. Minimum of oxidation indicated by Gruhl in zone of crystallographic transformation of lead oxide is confirmed. An induction period is observed at 535 C, which partially confirms parabolic results obtained by Weber and Baldwin. Granting that oxidation develops at different speeds under 475 and over 530, corresponding activation energies approach 6900 and 23,000 cal. 13 references.—MR. 16421

#### 3.8.4, 3.4.6, 6.2.2, 2.3.6

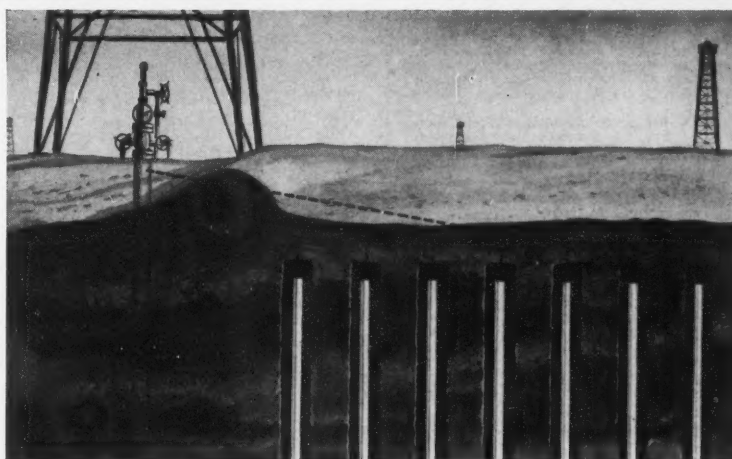
**Growth of Oxide Whiskers on Metals (Iron) at High Temperatures.** (In English.) Riitsu Takagi. *J. Phys. Soc., Japan*, 12, No. 11, 1212-1218 (1957).

The growth of whiskers of  $\delta$ -ferric oxide on pure iron in oxygen was studied by electron microscopy and diffraction at 400-850 C. A method was developed which avoids the ill effects of electron irradiation on natural growth. The growth mechanism is discussed, together with the relation of the thickness of the whisker to its length. The crystallographic orientation of the whiskers is deduced.—MA. 16412

#### 3.8.4

**Solid-Solution and Oxide Formation in the System Tantalum-Oxygen.** Erich Gebhardt and Hans Dieter Seghezzi. *Z. Metallkunde*, 48, No. 9, 503-508 (1957); *ibid.*, No. 8, 430 (1957).

Electrical resistivity measurements were used to study the kinetics of these processes at 800-1500 C and oxygen pressures of  $10^{-3}$  —  $2 \times 10^{-3}$  mm mercury. The maximum solid solubility,  $C_{max}$ , of oxygen in tantalum is 0.8 and 4.6 at.% at 800 and 1500 C, respectively.  $C_{max} = C_0 \exp(-\Delta H^0/RT)$ , where  $C_0$  is a constant and  $\Delta H^0$ , an enthalpy difference, = -8.8 kcal/mole. At 800-1000 C and  $10^{-3}$  mm mercury spontaneous oxidation occurs, whereas at 1500 C and  $10^{-3}$  mm mercury solid solution forms initially, and only when this becomes saturated does superficial oxidation take place. The saturated solid solution oxidizes at a rate in accordance with the Arrhenius equation  $\gamma = \gamma_0 \exp(-Q/RT)$ , and  $Q$ , the activation energy, = 14 kcal/mole; the oxide formed is  $Ta_2O_5$ . 19 references.—MA. 15843



## CAN YOU AFFORD LESS THAN THE BEST TO STOP WELL CASING CORROSION?

It is generally accepted that cathodic protection, using either rectifiers or magnesium anodes, will stop the external corrosion of oil well casing. To get protection at the lowest possible cost requires the services of an expert—with the knowledge, experience and instruments to do the job right.

CSI engineers pioneered and are acknowledged experts in this field. Perhaps their most important contribution is the "log current potential method" of determining the amount of electrical current required for casing protection. This inexpensive, surface method is **patented** (No. 2862177) and is licensed only to CSI. However, producing companies are granted free use of the method on their own wells.

To obtain valid data from this test method, the techniques and instrumentation must be handled correctly.

Be sure. For more information, call or write CSI today. Here's a case where the best costs no more! CSI offers the best in engineering and installation services, plus a complete line of quality materials. And CSI prices are competitive.



Cleveland 13, Ohio  
1309 Washington Ave.  
Tel. CHerry 1-7795

### CORROSION SERVICES INCORPORATED

General Office, Tulsa, Okla.  
Mailing Address:  
Box 787, Sand Springs, Okla.  
Tel. Circle 5-1351





## TECHNICAL REPORTS

on

### PROTECTIVE COATINGS

#### Other Than Pipe Line Coatings

**T-6A** Application Techniques, Physical Characteristics and Corrosion Resistance of Polyvinyl Chlor-Acetates. A Report of Unit Committee T-6A on Organic Coatings and Linings for Resistance to Chemical Corrosion. Publication 54-4. Per Copy \$5.50.

**T-6A** Report on Rigid Polyvinyl Chloride. A Report of NACE Technical Unit Committee T-6A on Organic Coatings and Linings for Resistance to Chemical Corrosion. Publication 55-4. Available only in April 1956 CORROSION at \$2.00 per copy.

**T-6A** Report on Epoxy Resins. A Report of NACE Technical Unit Committee T-6A on Organic Coatings and Linings for Resistance to Chemical Corrosion. Publication 56-5. Per Copy \$5.50.

**T-6A** Report on Application Techniques, Physical Properties and Chemical Resistance of Chlorinated Rubber Coatings. NACE Technical Unit Committee T-6A on Organic Coatings and Linings for Resistance to Chemical Corrosion. (Pub. 56-6.) Per Copy, \$5.50.

**T-6A** Vinylidene Chloride Resins. A Report of Unit Committee T-6A Prepared by Task Group T-6A-3 on Vinylidene Chloride Polymers. Publication No. 57-9. Per Copy \$5.50.

**T-6A** Reinforced (Faced) Tank Linings. A Report by NACE Committee T-6A. Pub. 58-7. Per Copy \$5.50.

**T-6A** Report on Thermoplastic Coal Tar Base Linings. A Report of NACE Unit Committee T-6A on Organic Coatings and Linings for Resistance to Chemical Corrosion, prepared by Task Group T-6A-16 on Coal Tar Coatings. Pub. 58-10. Per Copy \$5.50.

**T-6A-5** Application Techniques, Properties and Chemical Resistance of Polyethylene Coatings—A Report of NACE Task Group T-6A-5 on Polyethylene. Pub. 59-7. Per Copy \$5.50.

**T-6B** Protective Coatings for Atmospheric Use: Their Surface Preparation and Application Physical Characteristics and Resistance. A Report of Unit Committee T-6B on Protective Coatings for Resistance to Atmospheric Corrosion. Publication No. 57-10. Per Copy \$5.50.

**TP-6G** First Interim Report on Recommended Practices for Surface Preparation of Steel. (Pub. 50-5). Per Copy, \$5.50.

**TP-6G** Second Interim Report on Surface Preparation of Steels for Organic and Other Coatings. (Pub. 53-1.) Per Copy, \$1; five or more copies to one address, per copy \$5.50.

**T-6K** Acid Proof-Vessel Construction with Membrane and Brick Linings. A Report of NACE Technical Unit Committee T-6K on Corrosion Resistant Construction with Masonry and Allied Materials. Publication No. 57-6. Per copy \$5.50.

Remittances must accompany all orders for literature the aggregate cost of which is less than \$5. Orders of value greater than \$5 will be invoiced if requested. Send orders to National Association of Corrosion Engineers, 1061 M & M Bldg., Houston, Texas. Advise per package to the prices given above for Book Post Registry to all addresses outside the United States, Canada and Mexico.

## NATIONAL ASSOCIATION OF CORROSION ENGINEERS

1061 M & M Bldg. Houston 2, Texas

### 3.8.4, 3.7.4, 6.2.2

**Effect of Purity and Structure of the Metal on the Intergranular Diffusion of Oxygen in Iron.** (In French.) Raymond Sifferlen and Mme Claude Bourelle. Compt. Rend., 244, No. 24, 2928-2929 (1957).

In electrolytic iron annealed at 880 C, oxidation gives rise to oxide inclusions neither at the crystal boundary nor within the crystal; but if the metal is lightly deformed, say 6%, oxide inclusions are observed along the grain boundaries nearest to the interface. If these experiments are repeated with zone-refined iron deformed 6%, oxidation at 850 C no longer shows oxide inclusions at the grain boundaries or at the sub-boundaries.—MA. 16288

## 5. PREVENTIVE MEASURES

### 5.3 Metallic Coatings

#### 5.3.4

**Recent Developments in Gold Alloy Plating.** E. A. Parker. Technic, Inc. Plating, 45, No. 6, 631-635 (1958) June.

Recent developments in gold alloy plating are due largely to frowning ramifications of electronics field. Gold-antimony alloys are used in transistor field while connector field is using gold-nickel alloys for anti-galling surfaces. To eliminate delamination by standard gold plating procedure, printed circuit field is using gold-silver alloys which permit plating at room temperature and very low free cyanide. All of these alloys contain 95 or more gold. In low frequency connectors presence of nickel in gold lattice reduces diffusion of silver through gold layers. Major portion of such plating is done in barrels. Formulations are given for nickel plating baths (cyanide) for thin coatings and for plates heavier than 0.000020 in. Preparation of basis metal for gold alloy plating is considered.—INCO. 16955

#### 5.3.4, 8.9.2

**Automobile Bumper Plating.** G. H. Poll, Jr. Products Finishing, 22, No. 7, 26-33 (1958) April.

Description of copper, nickel and chromium plating of bumpers at Houdaille Industries, Huntington, West Virginia. Photos.—INCO. 16960

#### 5.3.4, 8.9.2

**Bright Crack-Free Chromium Plating at Cadillac.** H. Mahlstadt. Metal and Thermit Corp. Automotive Inds., 118, No. 10, 48-50 (1958) May 15.

Cadillac Motor Car Division of General Motors for the past eight months has been using a recently developed bright crack-free chromium plating on bumpers and bumper extensions of its cars. Tests have indicated that new chromium plating has greatly improved corrosion resistance over plating used previously, apparently because of absence of minute cracks formerly found in all chromium plating. Plate can be deposited on bright stainless steel as well as on other bright surfaces. Process is easier to operate than was bath for ordinary chromium plating. It activates the nickel base well. Throwing and covering powers of bath are far superior, particularly in recessed areas of parts, where ordinary chromium plate was not deposited to thickness desired. Still another advantage is fact that bright crack-free chromium can be replated, if necessary, without stripping,

something which was not possible with ordinary chromium plating. Corrosive materials most frequently found to attack automobiles are discussed. Photos.—INCO. 16899

#### 5.3.4, 6.2.2

**Aluminum Coating of Iron by Vaporized Aluminum Chloride.** (In Russian.) S. A. Semenkovich and A. V. Smirnov. Metalloved. i Obrabotka Metallov, 1958, 48-51, May.

Corrosion resistance of mechanical parts may be considerably increased by treatment with monohalogenides of aluminum. Under action of vaporized aluminum chloride, a hard, heat resistant coating is formed on iron surfaces at 950 to 1000 C. Apparently an intermetallic compound, Fe<sub>3</sub>Al, is formed. At higher temperatures the coating becomes softer and probably is made up of the eutectic mixture of Fe<sub>3</sub>Al and FeAl.—ALL. 16850

### 5.4 Non-Metallic Coatings and Paints

#### 5.4.5

**Points of Interest on Aluminum Pastes.** (In German.) J. K. Hartmann. Farbe u. Lack, 64, 77-78 (1958).

Aluminum powders are compared with aluminum pastes as raw materials for paints. The advantages of pastes are said to be: 1) though the pastes contain 35% solvents, they can be substituted pound for pound for aluminum powders without loss of hiding power; 2) and the more uniform dispersion in the vehicle gives improved corrosion protection; 3) the presence of a uniform layer of wetting agents on the pigment surface gives more lasting stability. Some specifications on aluminum pastes are quoted.—ALL. 16874

#### 5.4.7

**Vacuum-Metallizing Metal and Plastic Products.** C. Matilo, Jr. Ind. Finishing, 34, No. 5, 62-64 (1958).

Parts to be coated are skilfully loaded in rotating racks. The first application is a clear base coat by flow coating, then comes air drying, baking, vacuum metallizing, a clear top coat and baking. Dip dye coating for color, follows when specified.—RPI. 16962

#### 5.4.7

**Industrial Painting. Pt. III.** S. Clipson. Decorator, 57, No. 672, 65, 67-68 (1958).

In the concluding installment of this paper, the author stresses the importance of close contacts between painting instructors and industrial concerns in which painting contractors carry out their work. He goes on to indicate the tools and equipment needed for industrial and commercial painting, discusses the various methods of application, with special reference to spray-painting, and gives some suggestions of the ways in which instruction in the schools and colleges might be developed in relation to the present and future needs of the industry.—RPI. 16820

#### 5.4.7, 3.2.2

**New Technique Rids Plated Steel of Hydrogen Embrittlement.** H. H. Johnson, E. J. Schneider and A. R. Troiano. Case. Inst. Technology. Iron Age, 182, No. 5, 47-50 (1958) July 31.

To reduce hydrogen embrittlement in cadmium plated steels, a baking treat-

Over 20,000 cards have been issued by the NACE Abstract Punch Card Service.

ment is often specified. Its purpose is to recover ductility by driving hydrogen from steel. A typical recovery treatment consists of baking a cadmium plated part for several hours at 300-400 F. Such treatments are not always effective. Development of new procedure is described. A thin layer of cadmium is electroplated on the steel and this layer is then baked to recovery. Baking time is short because the plate is thin. A second layer of cadmium—of any thickness—is then deposited. Because first plate prevents entry of hydrogen, second plating has no embrittling effect. So efficient is this technique that no baking is needed after second plating. Graphs, 6 figures, 1 table.—INCO. 16876

## 5.4.8

**Bright Copper Plating of Articles with a Relief, from Acid Baths.** (In Russian.) V. P. Persiantseva et al. Metalloved. I Obrabotka Metallov, No. 9, 42-46 (1958) September. Translation Available from: Henry Bratcher, Technical Translations, P. O. Box 157, Altadena, Calif.

Advantages of bright copper plating from acid baths over polishing plus electroetching of protective-decorative three-layer copper deposits as used, for example, on printshop electrotypes. Merits and drawbacks of addition of thiourea as brightener. Description of plating practice developed by authors, and a method of eliminating the decomposition products of thiourea from bath. Experimental, pilot plant and full-scale plant procedures; results obtained. Effect of copper sulfate concentration on plate quality. Layout of commercial bright plating shop setup for filtering. Electrolyte recommended for commercial plating; resulting increases in production: 50 to 67%. 2 figures.—HB. 16887

## 5.4.8

**Coatings Help Metals Beat Heat.** J. V. Long. Solar Aircraft Co. Steel, 143, No. 4, 66-68 (1958) July 28.

Dipped, sprayed, baked or fired, coatings increase part life and upgrade resistance to corrosion and oxidation. Ceramic coatings increase fatigue life, prevent carburization, resist attack by molten zinc and aluminum and modify surface emissivity or reflectivity. Ceramics can be applied to any carbon steel and cast iron without any of the porcelain or ceramic coating defects. They protect carbon steel at 1100 F for long periods without discoloration. Studies show that certain refractory oxides, when powder flame sprayed, provide short time protection at temperatures over 3000 F. Zirconium and aluminum oxide have been kept in spotlight a great deal. A nickel-magnesium oxide also shows promise. Table gives protection time of a diffused aluminum coating on 321 stainless, Inconel X, Haynes Stellite 25 and C steel. Photos.—INCO. 16841

## 5.5 Oil and Grease Coating

## 5.5.1

**Lubricate Under Corrosive Conditions.** R. B. Norden. Chem. Eng., 65, No. 3, 154, 156, 158 (1958) Feb. 10.

Fluorinated oils, greases and waxes, chemically inert and thermally stable, are proving ideal as lubricants in contact with corrosive, hazardous chemicals. Low molecular weight fluoropolymers have proved resistant to compressed oxygen, mixed inorganic acids, caustic solutions, halofluoride gases,

oleum, red fuming nitric acid and 90% hydrogen peroxide. As far as corrosion effects, fluoropolymer oils are noncorrosive to metals up to about 350° F. One exception is copper which will discolor at temperatures over 120° F. Properties and applications are discussed.—INCO. 15495

## 5.5.3

**Rustproofing Oils for Processing.** Eugene R. Slaby. Socony Mobil Oil Co., Inc. Iron and Steel Engineer, 35, No. 1, 102-103 (1958) Jan.

Present-day slushing oils when correctly applied to sheet or strip steel can effectively safeguard surfaces against rust and corrosion; rust preventives permit shipment of coils without customary wrappings.—MR. 15504

## 5.5.3

**Sulfonates as Rust Preventives.** R. Simonoff. L. Sonneborn Sons, Inc. Petrochemical Ind., 1, No. 1, 35-37 (1958) June.

Oil-soluble sulfonates are excellent low cost rust preventive agents. Obtained during acid treating of petroleum fractions, the sulfonate molecule contains a polar grouping and hydrocarbon portion. The polar group gives an attraction to metal, the hydrocarbon residue an attraction to oil. Thus an oil film is held tenaciously to metal, barring penetration by water. Petroleum sulfonates with molecular weight above 400 can be classified oil-soluble or oleophilic, those below 400 as generally hydrophilic. Carrier is an oil, petroleum grease or wax, or a combination of the three. Photo.—INCO. 16864

**"BROTHER!" . . . "I stepped up the output on my well casing rectifiers yesterday because it was so dry . . .**

**Today we have a gully washer and I have to get out and set them back again before something blows."**



**PREVENT THIS WITH THE**

**NEW Good-All**

**AMP-O-MATIC**

**WELL CASING**

**Cathodic Protection Rectifier**

*Adjusts Output Itself!*

**An entirely NEW CONCEPT in Cathodic Protection.**

**NEW** Any amperage level from rated to minimum can be selected by moving the reactor control handle. No moving parts—no contacts.

**NEW** Automatically compensates for ground bed resistance and other circuit resistance variations.

**NEW** Built-in complete overload protection without interruption of output. Even short circuits will not shut the rectifier down or harm it in any way.

**NEW** Continuous output adjustment with single control.

**NEW** Reactor control—no moving parts—no contacts to change. Tops in reliability.

Reasonably priced—simplicity of design enables the Amp-o-matic to be priced for very little more than a conventional rectifier.

With an Amp-o-matic, simply set the rectifier for the amperage necessary to give protection and forget it. **Amp-o-matic does the rest—it compensates for changes in ground bed resistance or stack resistance, it cannot be overloaded, and it is extremely resistant to lightning damage.**

Get the complete story from your Good-All representative. Make your next system "Amp-o-matic".



**GOOD-ALL ELECTRIC MFG. CO.**

ELECTRICAL MECHANICAL DIVISION • OGALLALA, NEBRASKA



## TECHNICAL REPORTS

### on GENERAL CORROSION PROBLEMS

**T-3A** Some Corrosion Inhibitors—A Reference List. A Report of T-3A on Corrosion Inhibitors. Publication 55-3. Available only in April 1955 CORROSION at \$2.00 per copy.

**T-3B** Bibliographies of Corrosion Products. Section One—A Report by NACE Technical Unit Committee T-3B on Corrosion Products. Publication No. 57-5. Per Copy \$1.00.

**T-3B** Bibliographies of Corrosion Products. Section Two—A Report of NACE Tech. Unit Committee T-3B on High Purity Water. Pub. 57-21. Per Copy \$5.00.

**T-3B** Identification of Corrosion Products on Copper and Copper Alloys. A report of NACE Tech. Unit Committee T-3B on Corrosion Products. Pub. 59-13. Per Copy \$5.00.

**T-3C** Amount of Annual Purchases of Corrosion Resistant Materials by Various Industries—A Report of NACE Tech. Unit Comm. T-3C on Annual Losses Due to Corrosion. Pub. 59-8. Per copy \$5.00.

**T-3E** Tentative Procedures for Preparing Tank Car Interiors for Lining. A Report by NACE Task Group T-3E-1 on Corrosion Control of Railroad Tank Cars. Available only in June 1955 Corrosion at \$2.00 per copy.

**T-3F** Symposium on Corrosion by High Purity Water: Introduction to Symposium on Corrosion by High Purity Water, by John F. Eckel: Corrosion of Structural Materials in High Purity Water, by A. H. Roebuck, C. R. Breden and S. Greenberg; Corrosion Engineering Problems in High Purity Water, by D. J. DePaul: The Importance of High Purity Water Data to Industrial Application, by W. Z. Friend. A Symposium sponsored by NACE Technical Unit Committee T-3F on Corrosion by High Purity Water. Per Copy \$1.50.

**T-3F** Symposium on Corrosion by High Purity Water. Five Contributions to the Work of NACE Tech. Committee T-3F on High Purity Water. By A. A. Sugalski and S. L. Williams—Measurement of Corrosion Products in High Temperature, High Pressure Water Systems. By F. H. Krenz—Corrosion of Aluminum-Nickel Type Alloys in High Temperature Aqueous Service. By R. J. Lobsinger and J. M. Atwood—Corrosion of Aluminum in High Purity Water. By R. R. Dlesk—The Storage of High Purity Water. By D. E. Voyles and E. C. Fiss—Water Conditions for High Pressure Boilers. Pub. 57-22. Per Copy \$1.50.

**T-3F** Symposium on Corrosion by High Purity Water. Four Contributions to the Work of NACE Tech. Unit Comm. T-3F on High Purity Water. Pub. 58-13. Per copy \$1.50.

Corrosion Behavior of Zirconium-Uranium Alloys in High Temperature Water by W. E. Berry and R. S. Peoples.

Corrosion and Water Purity Control for the Army Package Power Reactor by R. J. Clark and A. Louis Medin.

Removal of Corrosion Products from High Temperature, High Purity Water Systems With an Axial Bed Filter by R. E. Larson and S. L. Williams.

Some Relations Between Deposition and Corrosion Contamination in Low Make-Up Systems for Steam Power Plants by E. S. Johnson and H. Kehmna.

**T-3G-3** Cathodic Protection of Process Equipment—A Report Prepared by NACE Task Group T-3G-3 on Cathodic Protection of Process Equipment. Pub. 59-9. Per Copy \$5.00.

**T-3H** Some Consideration in the Economics of Tanker Corrosion. A contribution to the work of Technical Committee T-3H on Tanker Corrosion by C. P. Dillon. Per Copy \$5.00.

Remittances must accompany all orders for literature the aggregate cost of which is less than \$5. Orders of value greater than \$5 will be invoiced if requested. Send orders to National Association of Corrosion Engineers, 1061 M & M Bldg., Houston, Texas. Add 60¢ per package to the prices given above for Book Post Registry to all addresses outside the United States, Canada and Mexico.

**NATIONAL ASSOCIATION  
OF CORROSION ENGINEERS**

1061 M & M Bldg. Houston 2, Texas

## 5.9 Surface Treatment

5.9.3, 3.5.8

**Study on Shot Peening.** M. Uchiyama and K. Kamishohara. Paper before Iron and Steel Inst. Japan, April, 1957; J. Iron and Steel Inst., Japan, 44, No. 2, 157-162 (1958) Feb.

Experiments to check residual stress and fatigue strength of peened nickel-chromium-molybdenum steel. Peening effect has two factors namely, residual stress effect and cleaning effect. Residual stress of the metal is decreased by heating it above 300 C and the degree of cleaning effect is affected by the initial surface conditions of the specimens. These effects are characterized by an increase of the fatigue strength. The shape of shot has some influence on the residual stress and the cleaning effect.—INCO. 16951

5.9.4, 3.5.9

**Protection of Springs of Steel EI 723 from High-Temperature Oxidation.** (In Russian.) T. I. Volkova and Yu. N. Griboedov. Metalloved. I Obrabotka Metallov, No. 5, 37-40 (1958) May. Translation available from Henry Bratcher, Technical Translations, P. O. Box 157, Altadena, Calif.

Development of a suitable surface treatment for flat springs of 0.20% carbon, 0.74 manganese, 2.3 chromium, 1.0 molybdenum, 0.45 vanadium, 0.010 phosphorus and sulfur each, max. steel for service at 500-550 C (930-1020 F) to improve the scaling resistance without appreciable impairment of the relaxation resistance. Details on heat treating practice. Experiments on chromizing and aluminizing (pack and contact-less) simultaneously with, or subsequent to, heat treatment: composition of impregnating compound; surface treating times and temperatures. Tests for oxidation resistance; relaxation resistance; micrographic analysis; hardness and microhardness measurements. Recommended surface treatment, 2 figures.—HB. 16861

## 6. MATERIALS OF CONSTRUCTION

### 6.2 Ferrous Metals and Alloys

6.2.4, 3.7.3

**High Strength Weldable Steels.** K. J. Irvine. Metallurgia, 58, No. 345, 13-23 (1958) July.

High strength steels are now being widely used in welded construction. Requirements of a high strength steel are given. Various ways in which steels can be strengthened and factors influencing weldability, pointing out advantages of a bainitic structure, are discussed. Nickel content of steels mentioned is given. Effect of additions of manganese, nickel and chromium were examined. It was shown that from series of manganese-nickel-chromium steels containing approximately 0.8 molybdenum and 0.15 carbon, steel containing approximately 0.8 manganese, 0.8 nickel and 0.8 chromium gave best combination of mechanical strength and weldability, while another suitable steel was 0.14 carbon, 1.23 manganese, 0.5 chromium and 0.25 molybdenum, which also showed good properties and was nickel free. Microstructure and properties of Fortiweld steel are described. Photomicrographs, graphs, tables. 24 references.—INCO. 16935

6.2.5, 8.8.5

**Cast Age-Hardenable Austenitic Steels.** E. A. Lange, N. C. Howells and A. Bukowski. Naval Research Lab. Rept. 5140, May 5, 1958, 14 pp. (PB 131733); Trans. Am. Foundrymen's Soc., 66, 519-525 (1958); Modern Castings, 34, No. 4, 53-59 (1958) Oct.

Chromium-nickel-phosphorus, chromium-manganese and chromium-nickel-manganese-vanadium types of age-hardenable, austenitic steels which have high strength characteristics in wrought forms were investigated for use as high-strength, nonmagnetic steels for castings. A chromium-nickel-phosphorus austenitic steel with 0.3 carbon and 0.25 phosphorus developed yield strengths at the 100,000 psi level. Chromium-manganese type of austenitic steels containing phosphorus or vanadium were age hardenable, but castings of these alloys were brittle when they were heat treated to high strength levels. Modifying the wrought chromium-nickel-manganese-vanadium composition resulted in an alloy with good ductility and yield strengths at the 100,000 psi level. A fourth type of age-hardenable, austenitic steel, manganese-vanadium, containing a minimum of alloying elements was developed. Hardness and tensile properties of four compositions which were cast and heat treated to yield strengths at 100,000 psi level are reported. Photomicrographs, tables.—INCO. 16823

6.2.5, 7.6.4, 3.5.9, 3.7.3

**On Austenitic Stainless Steel Tubes in Use for High Temperature and High Pressure Boilers.** T. Ikeshima, J. Omori, T. Okamoto, E. Miyoshi, S. Terai and H. Maruoka. Steel Tube Works, Sumitomo Metal Industries. Sumitomo Metals, 10, No. 1, 9-30 (1958) Jan.

Stainless steel tubes of types 321 and 347 used for super-heater in the modern power boilers were subjected to the examination of their physical properties at high temperature, creep rupture properties, brittleness after prolonged heating, oxidation resistance, welding and cold bending. Impact values of the specimens heated for 1000 hr at 600 C (1112 F), 650 C (1202 F), and 700 C (1292 F) will lower as temperature rises but they will never be downed below 5 kg-m/cm<sup>2</sup> which is serviceable for the actual uses. Sima phase is visible in the microstructure after a 1000 hr heating. Oxidation of these types of stainless steel is negligible at lower temperature than 700 C. Both arc welding and inert gas arc welding are applicable, although the latter is preferable. The key point of the welding is to select an adequate electrode. For welding of superheater tubes, electrodes of 19-9 niobium, 2-12 niobium and 18-12 molybdenum-niobium are most useful. But full care must be taken for welding practice and inspection after welding, because there are plenty of obstacles in the welding of stainless steel. Cold bending of the tube is possible even under a severe condition.—INCO. 16921

6.2.5, 3.5.8, 3.5.9

**Compressive Strength and Creep of 17-7 pH Stainless-Steel Plates at Elevated Temperatures.** B. A. Stein. Langley Aeronautical Lab. National Advisory Ctee. on Aeronautics, Technical Note 4296, July, 1958, 33 pp.

Compressive strength test results from room temperature to 1,000 F and compressive creep test results from 700 to 1,000 F are presented for plates of 17-7 pH stainless steel, Condition TH 1,050,



which were edge supported in V-groove fixtures. Plate width-thickness ratios range from 15-60. Master curves are presented which show combinations of average stress, temperature and time which produce give amounts of creep strain or failure of the plates and which facilitate interpolation of test results. Test results are compared with plate strengths and creep failure stresses determined from semiempirical approximations. Graphs, tables, diagrams.—INCO. 16950

#### 62.5, 8.8.5

**On Various Properties of Vacuum-Melted Heat-Resistant Alloys, Nimonic 80A, S816 and 13% Chromium Stainless Steel.** S. Koshihara and T. Kuno. Paper before Japan Inst. Met., October 1957. J. Japan Inst. Met., 22, No. 4, 169-173 (1958) April.

Heat-resistant alloys, Nimonic 80A, S816 and 13% chromium stainless steel were melted in the vacuum furnace and their various properties were tested in comparison with that of specimens melted in the atmosphere. When 13% chromium stainless steel was melted in vacuo, its gas contents and nonmetallic inclusions were largely decreased and its mechanical properties at elevated temperatures were improved. Particularly, corrosion resistance which is one of the most important properties of stainless steel, was remarkably improved by the vacuum melting. Same with Nimonic 80A and S816; their gas contents and nonmetallic inclusions were eliminated by the vacuum melting. Furthermore, the workability and mechanical properties at elevated temperature such as rupture strength and oxidation resistance were improved. These results indicate that meritorious effects on Nimonic 80A, S816 and 13% chromium stainless steel can be obtained by application of vacuum melting.—INCO. 16831

### 6.3 Non-Ferrous Metals and Alloys—Heavy

#### 6.3.10, 3.7.3

**Changes in the Properties of the Nickel-Chrome Alloy EI 765 for Stationary and Transport Turbines During a Process of Long-Term Isothermal Heat Treatment (up to 10,000 hours).** V. Z. Tseitlin and G. G. Morozova. Metaloved. I Obrabotka Metallov, No. 1, 30-35 (1958).

Alloys of this type at 700 and 750 C possess high stability in their physical properties for the duration of an extensive period. In particular, to judge by the course of the strain release curves, the resistance, will be maintained over a period of time considerably exceeding the duration of the experiments carried out. To a certain extent the same applies to the values for the impact strength and hardness. Graphs, photomicrographs.—INCO. 16872

#### 6.3.10, 3.7.3

**Welding of Nickel and High-Nickel Alloys in the Chemical Industry.** J. Hinde. Paper before International Institute of Welding, Vienna, June 1958. Brit. Welding J., 5, No. 7, 311-318 (1958) July.

After brief review of application of nickel and nickel alloys (nickel-copper, nickel-chromium-iron, nickel-molybdenum, nickel-molybdenum-chromium and nickel-chromium-molybdenum-iron) in chemical industry, metallurgical and practical aspects of welding these materials are considered, with particular reference to

# GALVAFROID®

gives the  
**CATHODIC  
PROTECTION**  
of  
hot-dip  
galvanizing



## EASILY APPLIED BY SPRAY OR BRUSH

Long used and field tested in England and other countries, the cathodic protection offered by GALVAFROID is now available for the first time in the United States.

Used as a self-finish, GALVAFROID provides the same cathodic protection as an equal weight of galvanizing—yet GALVAFROID is easily sprayed or brushed on any surface by unskilled labor.

Used as an undercoat for paint, GALVAFROID protects the exposed base metal, and prevents the radiating creep of rust from around scratch marks. Unlike the so-called Metallic Zinc Paints, GALVAFROID contains no zinc oxide or other pigments to inhibit electrical conductivity. The GALVAFROID film contains 92.95% metallic zinc.

Write for descriptive bulletin.

Technical representation open in some areas.

Full details on request.

# BART

MANUFACTURING CORPORATION

ELECTROFORMING • PIPE LINING & COATING  
PLATERS • CHEMICAL PUMPS • ENGINEERING DESIGN SERVICES  
227 Main Street, Dept. C, Belleville 9, N. J.

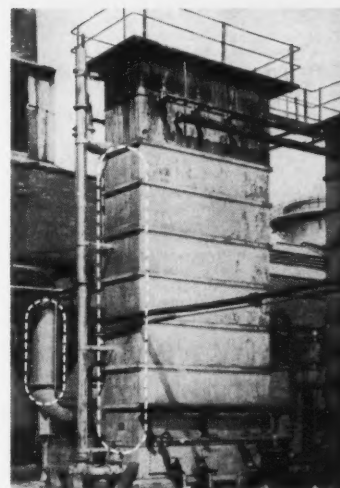


Illustration shows severe rusting of traditionally primed surfaces of gas plant equipment. However, note the absence of rust on the MAIN PIPE and ENDS OF EACH CONDENSER which were primed with GALVAFROID.



New bridge over the River Volta, Ghana, West Africa. GALVAFROID was used as a self-finish on all underside parts of this bridge.

maintenance of corrosion resistance across welded joints. Welding technique necessary to preserve continuity of cladding is described for steels clad with nickel or high-nickel alloys. Mention is also made of striplining of vessels and use of overlay techniques as means of economizing in use of materials. Tables list properties of nickel and nickel alloys in annealed condition, and filler wires and electrodes for welding these materials. Diagrams show joint designs. Photographs show low-carbon nickel caustic-soda evaporator, nickel heating coils for treatment of edible fats, Monel press roll, nickel vessel for salt evaporator and crystallizer, Inconel-clad steel reactor for Dowtherm heating and Monel stripper column.—INCO. 16827



## TECHNICAL REPORTS

on

### HIGH PURITY WATER CORROSION

- Symposium on Corrosion by High Purity Water by Committee T-3F on High Purity Water which includes:
- Introduction to Symposium on Corrosion by High-Purity Water by John F. Eckel.
- Corrosion of Structural Materials in High-Purity Water by A. H. Roebuck, C. R. Breder and S. Greenberg.
- Corrosion Engineering Problems in High-Purity Water by D. J. DePaul.
- The Importance of High-Purity Water Data to Industrial Applications by W. Z. Friend. Per Copy .....\$1.50
- Symposium on Corrosion by High Purity Water. Five Contributions to the Work of NACE Technical Committee T-3F on High Purity Water. Pub. 57-22.
- Measurement of Corrosion Products in High Temperature, High Pressure Water Systems by A. S. Sugalski and S. I. Williams.
- Corrosion of Aluminum-Nickel Type Alloys in High Temperature Aqueous Service by F. H. Krenz.
- Corrosion of Aluminum in High Purity Water by R. J. Lobsinger and J. M. Atwood.
- The Storage of High Purity Water by Richard R. Dlesk.
- Water Conditions for High Pressure Boilers by D. E. Voyles and E. C. Fiss. Per Copy .....\$1.50
- Symposium on Corrosion by High Purity Water. Four Contributions to the Work of NACE Tech. Comm. T-3F on High Purity Water. Pub. 58-13. Per Copy .....\$1.50
- Corrosion Behavior of Zirconium-Uranium Alloys in High Temperature Water, by W. E. Berry and R. S. Peoples.
- Corrosion and Water Purity Control for the Army Package Power Reactor by R. J. Clark and A. Louis Medin.
- Removal of Corrosion Products from High Temperature, High Purity Water Systems with an Axial Bed Filter by R. E. Larson and S. L. Williams.
- Some Relations Between Deposition and Corrosion Contamination in Low Make-up Systems for Steam Power Plants by E. S. Johnson and H. Kehmna.

Remittances must accompany all orders for literature the aggregate cost of which is less than \$5. Orders of value greater than \$5 will be invoiced if requested. Send orders to National Association of Corrosion Engineers, 1061 M & M Bldg., Houston, Texas. Add 60¢ per package to the price given above for Book Post Registry to all addresses outside the United States, Canada and Mexico.

**NATIONAL ASSOCIATION  
OF CORROSION ENGINEERS**

1061 M & M Bldg. Houston 2, Texas

#### 6.3.11, 3.5.9

**Behavior of the Platinum Metals at High Temperatures.** A. R. Powell. *Platinum Metals Rev.*, 2, No. 3, 95-98 (1958) July.

Prolonged heating in air of all the platinum metals results in more or less rapid loss in weight at temperatures above 1000 C; since this loss does not occur in inert gas atmospheres it has been attributed to the formation of volatile oxides. This is certainly true for osmium and ruthenium which form extremely volatile tetroxides, but so far the oxides responsible for the volatilization of the other members of the group have not been isolated and identified. Comparing behavior of platinum, rhodium and palladium in oxygen at high temperatures, it is concluded that platinum is the most and palladium the least, volatile at temperatures up to 1200 C whereas at 1300 C there is relatively little difference in the volatility of all three. The volatility of platinum in oxygen at 900-1100 C is appreciably reduced by alloying it with palladium or rhodium. Discussion is given of behavior of platinum as resistors and palladium-rhodium as thermocouples. Graph.—INCO. 16915

#### 6.3.20, 3.8.4

**Mechanism of Oxide Film Formation on Zirconium.** O. Flint and J. H. O. Varley. *J. Phys. Chem. Solids*, 6, 213-222 (1958) August.

Surface condition of zirconium controls both thermal and anodic oxidation. Effect of ultraviolet light. The interpretation suggested for these observations is in terms of the possible variation in electronic work function and defect state of the oxide depending upon the physical condition of the metal surface. These variations will affect the efficiency of anodic film formation, and a qualitative scheme of possible mechanisms whereby film growth is controlled is described. 11 references.—MR. 16856

### 8. INDUSTRIES

#### 8.4 Group 4

##### 8.4.2, 3.4.6

**Study of the Internal Corrosion of Pipes in the Transport and Distribution of Purified City Gas Under Various Pressures.** (In French.) J. Morlet. *Corrosion et Anticorrosion*, 6, 127-131 (1958) April.

Extent to which the corrosive action of purified city gas on soft steel pipe, in the absence or presence of condensed water, depends on its oxygen and carbon dioxide content and on pressure. Corrosion was found to be independent of pressure and of carbon dioxide content. Possibility of considerably decreasing the corrosive action of purified city gas by limiting its oxygen content or by dehydrating it, the latter being the more effective procedure.—MR. 16764

##### 8.4.5

**Recent Developments in Fluoride Volatility Processing of Reactor Fuels.** R. K. Steunenberg, J. Fischer, S. Vogler, M. J. Steindler, M. Adams, G. Goring, R. C. Vogel, W. A. Rodger, W. J. Mecham and W. B. Seefeldt. Argonne National Lab. U. S. Atomic Energy Commission Pubn., A/CONF.15/P/539, 32 pp. Prepared for the Second U. N. International Conference on the Peaceful Uses of Atomic Energy, 1958. Available from Office of Technical Services, Washington 25, D. C.

Development work on the processing of fuel alloys containing enriched uranium and zirconium is reported. The alloy is dissolved at a temperature of 600C in an approximately equimolar melt of sodium fluoride and zirconium fluoride, which is sparged with hydrogen fluoride vapor. The resulting tetrafluorides of zirconium and uranium dissolve in the melt as they are formed. The uranium is volatilized as the hexafluoride by sparging the melt with fluorine or bromine pentafluoride vapor. Data on the dissolution rates and the uranium volatilization have been obtained in both laboratory and semi-works investigations. Equipment problems are discussed and a design as well as initial operating experience is presented of a semi-works scale dissolver-hydrofluorinator of all graphite construction. Corrosion data on metal and graphite under dissolution conditions are reported. Included are recent studies relating to fission product behavior in fluoride systems, the corrosion rates of certain metals in fluoride at elevated temperatures and the handling of plutonium hexafluoride in the vapor phase. (auth)—NSA. 16847

##### 8.4.5, 6.4.2

**Research Findings Speed Nuclear Progress.** D. Lillie. *General Elec. General Elec. Rev.*, 61, 43-45 (1958) July.

Some results of General Electric's research in nuclear structural materials and fuels are discussed and appraised. Stainless steel, zirconium and aluminum are evaluated as fuel cladding materials. While aluminum has advantage of low neutron-absorption cross section (0.22 barns, compared to 2.85 for stainless steel), its chief drawback is catastrophic corrosion in 300 C water. Addition of nickel to aluminum is effective through protective modification of protective film, particularly through formation of complex aluminum-nickel oxides. Iron-silicon and iron-aluminum alloys are considered. Alloying with copper, molybdenum, nickel, zirconium and aluminum is not effective in improving ductility of iron-6 silicon alloys.—INCO. 16829

##### 8.4.3, 4.3.2, 6.3.10

**What to Do About Corroding Isomerization Units.** J. F. Mason, Jr., and C. M. Schillmoller. *Inco. Petroleum Refiner*, 37, No. 7, 103-106 (1958) July.

Reviews some case histories of corrosion problems encountered in butane isomerization units and points out where corrosion has occurred or can normally be expected to occur. Remedial steps are indicated. Effects of hydrochloric acid concentration and solution temperatures on corrosion rate of nickel and its alloys (nickel-copper, nickel-molybdenum and nickel-silicon) are summarized with graphs. In vapor phase butane process, corrosive conditions result from formation of dilute hydrochloric acid and sludge. Importance of keeping system dry and free from olefins, sulfur and pentanes cannot be over-emphasized. In liquid phase butane process, due to corrosive nature of catalyst (aluminum chloride in antimony trichloride), reactors, vessels, pumps and transfer lines in catalyst service are clad or lined with nickel or alloy boron (nickel-molybdenum-iron alloy).—INCO. 16953

##### 8.4.5, 5.11, 2.3.8

**Engineering Design of Oak Ridge Fluoride Volatility Pilot Plant.** R. P. Milford. *Oak Ridge National Lab. Ind. and Eng. Chem.*, 50, No. 2, 187-191 (1958) Feb.

Describes fluoride volatility process which appears promising as a method of recovering uranium from nuclear reactor fuel elements of the zirconium type. Fluorinator is fabricated from L-Ni. Although rod-type electrical heaters banded with stainless steel shimstock are used in a few cases to maintain temperature of molten salt transfer lines above melting point of salt, principal method of heating was "autoresistance"—a process of heating pipes or tubes by passing electrical current through pipes or tube walls. Inconel was used because of its high electrical resistivity, coupled with its corrosion resistance to fused fluoride salts being transferred. Absorbers and uranium hexafluoride cold traps are fabricated from Monel. Uranium hexafluoride lines that cannot be run through ducts are heated by No. 20 Nichrome wire with asbestos insulation and Monel braid. Diagrams, photos.—INCO. 16961

## 8.4.5, 6.3.20

**HRP Radiation Corrosion Studies: In-Pile Loop L-4-11.** J. R. McWherter and J. E. Baker. Oak Ridge National Lab. U. S. Atomic Energy Commission Publ., ORNL-2152, June 27, 1958, 50 pp. Available from Office of Technical Services, Washington, D. C.

The sixth in-pile loop experiment, L-4-11, was completed. The loop operated in-pile for a total of 1109 hr, during which time the LITR energy output was 2175 Mw. The main-stream operating temperature was 250 C. During this run the loop was drained and then recharged with fresh solution. Based on oxygen data, the corrosion rate for the first 110 hr of operation was 5.0 mpy; for the next 232 hr the rate was 1.7 mpy. For the first 120 hr of operation with the second fuel solution the corrosion rate was 7.2 mpy, and for the remainder of the run the rate was 1.9 mpy. The nickel data gave parallel results. Cor-

rosion specimens of a large variety of zirconium alloys, titanium alloys and stainless steels, as well as specimens of synthetic sapphire, sintered alumina, platinum and Incoloy, were included in the experiment. Corrosion rates of most of the zirconium alloys, titanium alloys and stainless steels were generally consistent with rates observed in the previous in-pile loops. The zirconium alloys zirconium-3 (3% silver), zirconium-3 (0.52% tin, 5.71% titanium, 40 ppm nitrogen), zirconium-3 (0.52% tin, 0.28% iron, 5.66% titanium, 60 ppm nitrogen), zirconium-3 (1.4% iron), and zirconium-4 (0.7% iron, 2.8% chromium) corroded at rates about two to three times those observed for Zircaloy-2 at the same power density. The zirconium alloy containing 3.84% aluminum and 2.5% manganese corroded at rates about 10 to 20 times those for Zircaloy-2. The zirconium alloy containing 2% niobium corroded at the same rate as Zircaloy-2

## CORROSION ENGINEERING DIRECTORY

**WAYNE BROYLES**  
CATHODIC PROTECTION  
Installation  
DESIGN SURVEYS  
**ENGINEERING CORP.**  
P.O. Box 1169 • Fairfax 3-6858 • Houston 1, Texas

**Electro Rust-Proofing Corp.**  
Engineering Division  
Corrosion Surveys  
Cathodic Protection Design  
Plans • Specifications  
Electrolysis Control  
Testing  
BELLEVILLE 9, NEW JERSEY  
Atlanta • Chicago • Dallas • Monrovia

**SOUTH FLORIDA TEST SERVICE**  
INCORPORATED  
Testing—Inspection—Research—  
Engineers  
Consultants and specialists in corrosion,  
weathering and sunlight testing.  
4301 N.W. 7th St. • Miami 44, Florida


**cathodic protection service**  
  
Twenty cathodic protection  
engineers with a combined  
total of over 150 years experi-  
ence available to serve you  
with ABILITY and INTEGRITY.  
Houston, 4601 Stanford St.  
BRANCH OFFICES  
Tulsa • New Orleans • Corpus Christi • Denver

**CATHODIC PROTECTION**  
• ENGINEERING  
• SURVEYS • CONSTRUCTION  
Systems for conventional and  
specialized applications  
**THE HARCO CORPORATION**  
4592 East 71st St. VULcan 3-8787  
Cleveland 25, Ohio

**FRANCIS W. RINGER ASSOCIATES**  
• Consulting  
Corrosion  
Engineers  
7 Hampden Ave. MOhawk 4-2863  
NARBERTH (Suburb Phila.) PENN.

**Cathodic Protection**  
SURVEYS • DESIGNS • ENGINEERING  
Pipes Lines • Offshore Platforms  
Refinery and Gasoline Plant Lines  
Municipal Systems • Barges  
**CORROSION RECTIFYING CO.**  
5310 ASHBROOK PHONE: MO 7-6659  
P. O. BOX 19177 HOUSTON, TEXAS

**THE HINCHMAN CORPORATION**  
Consulting Engineers  
"World-Wide Activities"  
Survey • Design • Supervision  
Specializing In  
Corrosion Control • Radio Interference Studies  
F.C.C. Certification Tests  
Francis Palms Bldg., Detroit, Michigan

**WATER SERVICE LABORATORIES, INC.**  
  
Specialists in  
Water Treatment  
Main Office, 615 West 131st St., N.Y. 27, N.Y.  
Offices Also in Philadelphia, Washington and  
Richmond, Va.

**CORROSION SERVICE LIMITED**  
Offers in CANADA  
A Complete Service in Corrosion Engineering  
Design and Installation of Cathodic Protection  
Systems.  
Resistivity and Electrolysis Surveys  
Selection and Application of Protective Coatings.  
17 Dundonald St., Toronto, Canada

**iccc** Interprovincial  
Corrosion Control Company  
Limited  
100 Examiner P. O. Box 167, Burlington,  
Bldg., Calgary Ontario  
Alberta CANADA  
CONSULTING ENGINEERS  
Survey — Design — Materials and Equipment  
Installations

**CORROSION ENGINEERING**  
**EBASCO SERVICES**  
INCORPORATED  
TWO RECTOR STREET, NEW YORK 6, N. Y.  
CHICAGO • DALLAS • PORTLAND, ORE.  
SAN FRANCISCO • WASHINGTON, D. C.

**A. V. SMITH**  
**ENGINEERING CO.**  
CONSULTING ENGINEERS  
Essex Bldg. 119 Ann Street  
Narberth, Pa. Hartford 3, Conn.

**You can advertise your engi-  
neering services in this di-  
rectory for about \$1.50 a  
thousand readers. This is by  
far the best, least expensive  
and most convenient way to  
keep your name before the  
more than 8000 paid read-  
ers of CORROSION. Write  
for rates, 1061 M & M Bldg.,  
Houston 2, Texas.**



in the core but at a much higher rate, 17 mpy, in the in-line position. However, a zirconium alloy containing 15% niobium corroded at less than one-third the Zircaloy-2 corrosion rates in the core and exhibited rates similar to Zircaloy-2 in the in-line position. Corrosion rates for Incoloy were found to be about the same as those for stainless steel exposed to similar conditions. All sintered aluminum oxide specimens in the main stream disintegrated; however, the aluminum oxide bearings in the low temperature region of the pump showed no measurable wear. Synthetic sapphire became cloudy and corroded at a rate of 12 mpy. Platinum was slightly affected in the core. (auth)—NSA. 16972

#### 8.4.5

**The Manufacture of PWR Blanket Fuel Elements Containing High Density Uranium Dioxide.** J. Glatter, E. F. Losco, W. J. Hurford, J. S. Theilacker, R. L. Fischer, N. T. Saunders and R. A. Wolfe. Westinghouse Electric Corp. U. S. Atomic Energy Commission Pubn., A/CONF.15/P/2380, 42 pp. Prepared for the Second U. N. International Conf. on the Peaceful Uses of Atomic Energy, 1958. Available Office of Technical Services, Washington, D. C.

An account is given of the accomplished production of the blanket fuel elements for the first Pressurized Water Reactor core and of the current status of development on the blanket fuel elements for the second core. High density uranium dioxide cylindrical pellets were utilized in the rod type unbonded fuel element of the first core. Dense uranium dioxide wafers are currently under development for use in a flat type unbonded fuel element for the second core. The methods and techniques utilized for fabricating the fuel rod bundles are described in detail. The methods for fabricating the shells and shell assemblies are given in detail. Integrated with the engineering and manufacturing account of each of the blanket fuel element components is a description of the quality evaluation methods used. The manufacturing costs and yields for each of the blanket components for the first core are also presented. A method of fabricating a plate type, dense uranium dioxide bearing fuel element consistent with the realization of desired mechanical rigidity is described. Mechanical properties, corrosion, corrosion resistance data and irradiation stability information is presented to illustrate the current evaluation of performance of the flat plate type unbonded fuel element contemplated for use in the second core. (auth)—NSA. 16931

#### 8.4.5, 3.5.4

**Development of High Power Irradiators.** B. Manowitz, O. Kuhl, D. Richman and L. Galanter. Brookhaven National Lab. U. S. Atomic Energy Commission Pubn., A/CONF.15/P/1069, 20 pp. Prepared for the Second U. N. International Conf. on Peaceful Uses of Atomic Energy, 1958. Available Office of Technical Services, Washington, D. C.

Two systems are considered—one a nuclear reactor through which an aqueous solution of an indium salt is circulated and subsequently also circulated through the irradiator; the other, a device made up of plates of Co<sup>60</sup>. Experimental data are presented on corrosion behavior of indium solutions against various materials of construction, stability of indium solutions and dose distribution of radiations from indium solutions in an absorbing medium. The

dose distribution study was made on large-scale, low-level irradiators. Experimental results are compared with theoretical. From the experimental data on dose received at a known curie input, the power required for the nuclear reactor in order to achieve full-scale throughput is estimated. Design parameters for the cobalt-60 irradiator are analytically determined. Some experimental data are compared with the theory. (auth)—NSA. 16893

#### 8.4.5, 4.7

**Metallurgical Problems in Molten Fluoride Systems.** W. D. Manly, J. H. Coobs, J. H. DeVan, D. A. Douglas, H. Inouye, P. Patriarca, T. K. Roche and J. L. Scott. Oak Ridge National Lab. U. S. Atomic Energy Commission Pubn., A/CONF.15/P/1990, 30 pp. Prepared for Second U. N. International Conference on Peaceful Uses of Atomic Energy, 1958. Available Office of Technical Services, Washington, D. C.

The important metallurgical problems relevant to circulating fuel reactors utilizing fused fluoride systems are discussed. The successful utilization of such mixtures is in large measure dependent upon the development of reactor materials which can both contain the mixtures under reactor conditions and afford useful structural properties. Paramount among the materials requirements which must be fulfilled are the following: resistance to corrosion by the fluoride fuel or salt (in the presence of a neutron flux), resistance to oxidation by air and good elevated-temperature strength. Materials must also be easily formed and welded into relatively complicated shapes and be metallurgically stable over a wide temperature range. The most stringent materials requirement is adequate corrosion resistance to the molten fluorides which are used as fuel carriers. Generally speaking, corrosion problems are solved by either formation of a protective film through action of the corrosive environment or the establishment of thermodynamic equilibrium between the material and corrosive environment before significant corrosion occurs. The first approach has been used quite successfully with metals exposed to gas or high-temperature water but with only limited success with liquid metals and molten salts. For the latter, especially molten fluorides which are excellent fluxing agents, the second approach, i.e., thermodynamic equilibrium, is preferred. (auth)—NSA. 16918

#### 8.4.5, 4.7

**Liquid Metal Fuel Reactor and LMFRE-I.** Clarke Williams and Robert T. Schomer. Brookhaven National Lab. and Babcock and Wilcox Co. U. S. Atomic Energy Commission Pubn., A/CONF.15/P/2355, 28 pp. Prepared for the Second U. N. International Conference on the Peaceful Uses of Atomic Energy, 1958. Available from Office of Technical Services, Washington, D. C.

An outline of the progress in the liquid metal fuel reactor program since the last Geneva Conference is presented, along with the results of a number of feasibility and economic evaluation studies on various liquid metal fuel reactor designs. Exponential and critical experiments are underway to establish core design parameters. The chemistry research to date indicates that either continuous processing plants or batch processing is feasible for the uranium-bismuth circulating fuel. 2½ chromium-1 molybdenum has been extensively tested in thermally convected and pumped loops

and appears to be a possible container material. Steels with lower chrome or no chrome content appear to corrode even less. Graphite exposed to bismuth-uranium solution appears to be a satisfactory container material. Studies are underway on slurries both of ThBi<sub>2</sub> and thorium dioxide in liquid bismuth. Of the various designs considered, the most attractive appears to be a single region reactor in which the fuel mixture of U<sup>233</sup>-thorium-bismuth is circulated through an external heat exchanger. A two region reactor with U<sup>233</sup>-bismuth solution fuel circulates through the core and a ThBi<sub>2</sub> in liquid bismuth slurry is circulated through a blanket region surrounding the core and separated from it by a graphite burner. (auth)—NSA. 16890

#### 8.4.5, 6.2.2

**Iron-Aluminum Base Alloys for Reactor Components.** William A. Maxwell, Blake King, J. Mueller and N. Ida. Martin Co. U. S. Atomic Energy Commission Pubn., A/CONF.15/P/707, 18 pp. Prepared for the Second U. N. International Conference on the Peaceful Uses of Atomic Energy, 1958. Available from Office of Technical Services, Washington, D. C.

Each of the materials presently available for cladding fuel elements and other power reactor core components is shown to represent a poor compromise as far as nuclear, physical, chemical and cost characteristics are concerned. Alloys based on the iron-aluminum system are noted to be cheap, extremely corrosion-resistant and to have only a moderate neutron-capture cross section. Their usefulness as canning materials is described as having been greatly limited, however, by their brittleness and poor high-temperature strength. The procedure followed by the authors in a current program aimed at developing families of ductile iron-aluminum base alloys for use in water-cooled, liquid-metal cooled and gas-cooled reactors is described. The metallurgical peculiarities of iron-aluminum alloys are discussed and the reasoning followed in selecting desirable alloying additions is outlined. The importance of close integration of alloy preparation, fabrication methods development and testing activities is emphasized. Properties of promising interim alloys are compared with corresponding properties of currently available materials, and are discussed in relation to the economics of reactor construction and operation. Their peculiar combination of corrosion resistance and ease of reprocessing is pointed out as a major advantage of iron-aluminum base alloys. Special emphasis is given to an evaluation of the effects of nuclear bombardment on the structure of these alloys. It is concluded that the required ductility and high-temperature strength can be imparted to iron-aluminum base alloys, and that they are likely to become competitive with stainless steels, zirconium alloys and other materials on the basis of over-all fuel-cycle costs. (auth)—NSA. 16932

#### 8.4.5, 3.5.4, 5.4.3

**An Evaluation of Asphalt and Other Materials for Lining Radiochemical Waste Storage Basins.** Arnold J. Hoberg, Clyde D. Watson and George A. West. Oak Ridge National Lab. U. S. Atomic Energy Commission Pubn., ORNL-2508, Sept. 10, 1958, 50 pp. Available from Office of Technical Services, Washington, D. C.

Asphaltic membranes appear practical for lining earth storage pits for aqueous radioactive waste provided that the wastes are neutralized and are decayed sufficiently that the self-heating temperature does not exceed 150 F and the time for the asphalt to acquire a dose of 10<sup>6</sup>r is more than 25 years. In laboratory tests gamma irradiation of asphalts caused: evolution of hydrogen and carbon dioxide, resulting in 14 to 30% volume increase and a honeycomb structure; increase in softening point, slight increase in ductility and decrease in penetration; decrease in flash point but no increase in "loss on heating"; increase in asphaltene and resins and decrease in oils. The addition of mineral fillers was not beneficial. Prefabricated asphaltic membrane and plank samples were still serviceable after 10<sup>6</sup>r irradiation. Irradiated tars showed some change in ductility but little change in other physical properties. In 1- to 4-week immersion tests, asphalts deteriorated in simulated acid waste solutions above 150 C, but changes were slight when the nitric acid concentration was < 1%. Chemical damage to tars appeared to be similar to that of asphalts but the physical changes were not actually measured. In 1-year field tests an asphaltic membrane remained impervious to passage of neutralized waste containing 10<sup>-3</sup> curie/liter and a prefabricated asphalt plank sagged 1.5 in. but did not rupture while supporting 2 ft. of gravel. In survey studies, soil solidified with liquid silicate conditioners was stable in acid waste but not in water or caustic waste. It was calculated that wastes from fuels irradiated to 10,000, 3,300 and 1,000 Mwd/ton and decayed 6 years would irradiate an asphalt lining to 10<sup>6</sup>r in 20, 79 and 300 years, respectively; with 10 years' decay the times would be 27, 95, and 365 years. Longer decay times offer little, if any, advantage. An open pit of 10<sup>6</sup> gal. capacity could be constructed for \$0.03 per gallon, and one with a concrete roof for \$0.07 per gallon; corresponding costs for a 5 x 10<sup>6</sup> gal. pit would be \$0.02 and \$0.05 gallon. (auth) —NSA. 16853

#### 8.4.5, 6.3.17

**Uranium Dioxide—A Promising Nuclear Fuel. A Metallurgy Seminar Presented at the University of Toronto, January 24, 1958, and at McMaster Univ., March 6, 1958. O. J. C. Runnalls. Atomic Energy of Canada, Jan., 1958, 35 pp. Available from the Scientific Document Distribution Office, Atomic Energy of Canada, Ltd., Chalk River, Ontario, Canada.**

Canada's need for power is dealt with briefly. Experience with uranium metal in the NRX Reactor in relatively cold water and experiments with hot water which indicate that uranium metal is unsatisfactory for water-cooled power reactors are discussed. Information is presented to support the contention that zirconium alloy clad uranium dioxide will meet the required specifications of corrosion resistance, irradiation stability and economic fabrication costs. Photographs illustrating variations in corrosion behavior, radiation effects, and fabrication techniques for uranium and uranium dioxide are given.—NSA. 16865

#### 8.4.5, 5.11

**Mechanical and Thermal Problems of Water Cooled Nuclear Power Reactors. N. J. Palladino and J. Sherman. Paper before 2nd Nuclear Eng. and Science Conference, Philadelphia, March 11-14,**

1957. Am. Soc. Mechanical Engrs., Paper No. 57-NESC-119, 1957, 9 pp.

Discusses principal problems faced in mechanical and thermal design of cores for pressurized water reactors. All material used in reactor design must first be compatible with cooling fluid in plant. Basic material used in high temperature water for static parts of reactor such as core structural supports is stainless Type 304 or 347. In order to conserve fuel inventory, fuel element cladding materials should have low neutron absorbing properties; this has led to extensive use of zirconium and zirconium alloys. Power cores have been proposed using stainless steel cladding. Rubbing parts on Pressurized Water Reactors are made of 17-4 PH or chromium-plated stainless and various grades of Stellites. In design of pressure vessels, chief problem is that of achieving heavy

sections with stainless steel suitably bonded to carbon steel so as to obtain corrosion resistance of stainless with relative strength, weldability and availability of carbon steel. Use of 410 stainless is necessary on mechanism housings of Pressurized Water Reactors vessel because of its magnetic properties.—INCO. 16269

#### 8.4.2

**Problems of Importing Natural Gas. A. R. Myhill. Chem. and Process Eng., 39, No. 1, 24-26 (1958) Jan.**

Discussion of recent advances in liquefaction, storage and transportation of natural gas which point to a possible way of easing Britain's gas supply problems. Technical considerations involved are examined. Insulated reception tanks made of special alloys are being constructed at Canvey Island in the Thames Estuary. Only a limited

wherever you have  
a corrosion problem...



Standard Magnesium  
has the answer...

Whether it's pipelines or well casing, tanks or filters, offshore units or marine vessels, Standard Magnesium has the answer to any corrosion problem. With over 300 standard magnesium anode designs, designs that have proved their effectiveness in installation after installation, Standard Magnesium has the anode to fit any cathodic protection need.

Standard Magnesium anodes are available in either the conventional H-I alloy anode, or the special High Current anode. High current anodes are designed for high resistance soil conditions and produce 50% greater current output than conventional anodes. Either can be supplied bare or in our exclusive Vibra-Pak package for special soil conditions.

No matter what the installation, Standard Magnesium anodes will provide better, more economical protection.

NOW AVAILABLE!



1. ADVANTAGES OF HIGH CURRENT ANODES
  2. HOW TO PREVENT SEAWATER CORROSION
  3. HOW TO PREVENT CORROSION OF TANKS
- Send for your FREE copies today

QUALITY AND DEPENDABILITY THROUGH RESEARCH



Standard Magnesium  
Corporation

7500 EAST 41ST STREET — TULSA, OKLAHOMA

MAGNESIUM INGOT • MAGNESIUM ANODES • MELTING FLUX



amount of information is available on the construction and operation of storage tanks for liquids at low temperatures but several large tanks have been built for the reception of liquid oxygen, of the double-shell cylindrical pattern with inner container of stainless steel insulated by powder material of the expanded volcanic dust type. Diagram shows one design proposed for storing liquefied gas in Chicago which provides for 19 vertical containers in the form of copper-nickel cylinders arranged in a cluster within an insulated tank having a copper lining and a mold-steel shell. Photo.—INCO. 16543

#### 8.4.3, 3.4.8, 3.2.2

**Corrosion in Cat Reformers with Naphtha Pretreaters.** E. B. Backensto and R. W. Manuel. Paper before Am. Petroleum Inst., Refining Div., Annual Mtg., Los Angeles, May 12-15, 1958. *Oil & Gas J.*, 56, No. 20, 131-135 (1958) May 19.

Experience with catalytic reformers having naphtha pretreaters has borne out predictions that desulfurization of charge to below 0.002% by weight of sulfur would reduce high-temperature hydrogen-hydrogen sulfide corrosion of carbon and low chromium steels in reforming section to a negligible level. Sulfide scaling has been prevented by use of 18-8 chromium-nickel stainless steel and calorized coatings. Corrosion and fouling by chlorides in low-temperature sections of pretreater were controlled by injection of ammonia and inhibitors and by use of Monel alloys. Transgranular stress-corrosion cracking of austenitic stainless steel by chlorides is being prevented by washing piping and exchangers with water and dilute alkaline solutions during shutdowns. Intergranular cracking of unstabilized austenitic alloy lining has occurred in 1 pretreater reactor, probably as a result of polythionic acids formed by action of wet steam on sulfide scale, but has not occurred in units where stabilized alloys are used and contact of wet steam is avoided. High-temperature hydrogen attack was observed on a few carbon steel internal details in reactors, but generally hydrogen damage was avoided through use of chromium and molybdenum steels for exposed parts and by adequate insulation of carbon steel. Photos, photomicrographs.—INCO. 16465

#### 8.4.5, 3.5.4

**The Effect of Nuclear Radiation on Structural Metals.** B. C. Allen, A. K. Wolff, A. R. Elsea and P. D. Frost. Battelle Memorial Inst. U. S. Atomic Energy Commission Pubn., Contract AF33(616)-5171, May 31, 1958, 40 pp. Available from Battelle Memorial Inst., Radiation Effects Information Center, Columbus, Ohio.

The general effects of various types of radiation on metals are discussed and the damage mechanisms are outlined. Following this is a topical discussion of the effects of fast neutrons on the physical and electrical properties and corrosion resistance of metals. Tabular data are presented on these effects. Experimental evidence to date indicates that structural metals are quite resistant to nuclear radiation when compared to such things as organic compounds or electronic components. Fast neutrons in integrated flux levels above  $10^{19}$  nvt represents the only reactor radiation that can significantly affect the properties of structural nonfissionable metals. (auth)—NSA. 16451

#### 8.4.5, 3.5.9, 4.7

**Examination of Fluoride Pump Loops 4935-5 and 4935-7.** R. S. Crouse, J. H. DeVan and E. A. Kovacevich. Oak Ridge National Lab. U. S. Atomic Energy Commission Pubn., CF-55-10-31 (Del.), October 5, 1955 (Declassified with Deletions March 12, 1957), 11 pp. Available from Office of Technical Services, Washington, D. C.

The two gas-fired pump loops are a part of a series being run to determine the effect of wall temperature on mass transfer in an Inconel-fused fluoride system. The corrosion of the loops is evaluated.—NSA. 16160

#### 8.4.5, 3.5.4

**The Metallurgy of EBWR.** K. F. Smith. Argonne National Lab. Metal Progress, 72, No. 5, 79-83 (1957) Nov.

Discusses new alloys and new fabricating techniques developed to meet unusual conditions of irradiation and corrosion encountered in experimental boiling water reactor. Alloying uranium with 5 zirconium and 1½ niobium, followed by gamma quench and isothermal treatment, produced fuel with stability under irradiation, corrosion resistance superior to that of unalloyed uranium, and rolling characteristics compatible with Zircaloy-2 cladding. Plate rolling techniques and welding of plates to form subassemblies is described. Effect of irradiation on impact strength of pressure vessel steel is considered; data for A-212 steel are shown in graph. Interior of pressure vessel is clad with Type 304. Boron stainless steel is used for thermal shield and control rods; boron is absorptive agent for excess neutrons. Problem of boron changing to lithium plus helium under irradiation is present. Diagram of reactor is shown.—INCO. 16289

#### 8.4.5, 3.5.4, 3.4.7

**Radiation Versus Film Formation.** Final Report. Problem Assignment No. 124-X14E. S. Kuniansky and R. B. Briggs. Chicago Univ. Metallurgical Lab. U. S. Atomic Energy Commission Pubn., CE-2816, May 7, 1945 (Declassified Feb. 19, 1957), 34 pp. Available from Office of Technical Services, Washington, D. C.

Experiments in capillary tubes in the Clinton pile indicate that radiation in a 250,000 Kw pile will have little or no effect on the rate of film formation at pH>7. At pH<7 radiation appears to increase the rate of film formation if sodium dichromate is present in the water, probably due to the deposition of hydroxides of chromium. Experience with the experimental water tubes in the Clinton pile indicates that little trouble may be expected from film formation if the pH is maintained above 7 and the concentration of iron is kept below 0.05 ppm. Addition of some sodium silicate to the water reduces the rate of film formation, however, there is evidence which indicates that the presence of sodium silicate in concentrations as great as 40 ppm, calculated as SiO<sub>2</sub>, may result in the formation of a less easily removable film. (auth)—NSA. 16211

#### 8.4.5, 6.2.1, 6.6.5

**The Choice of Structural Material for Nuclear Power Stations.** Charles E. Reynolds. Simon-Carves, Ltd., London. Atomic Energy Rev., 1, 72-77 (1957), September.

A discussion is presented on the choice of structural materials such as

steel and concrete for nuclear power stations. The factors considered are the costs, availability, durability, maintenance, fire resistance, watertightness and resistance to corrosion.—NSA. 16397

#### 8.4.5, 6.4.2

**Corrosion and Aluminum Activity in Pile Water.** Progress Report-Problem Assignment Nos. 124-X1E and 124-X11E. W. P. Jesse, M. C. Leverett, W. D. B. Spatz, and R. B. Briggs. Clinton Laboratories. U. S. Atomic Energy Commission Pubn., CT-1440, May 15, 1944 (Declassified Feb. 18, 1957), 32 pp. Available from Office of Technical Services, Washington, D. C.

The corrosion rate of 2S aluminum in the X pile under simulated W conditions is about 1/7 that calculated from the Al<sup>3+</sup> activity in the pile effluent water. It is proposed that the discrepancy is due to the aluminum oxide film where, it is postulated, Al<sup>3+</sup> atoms are formed and from which they escape into the cooling water by diffusion. The corrosion rate measured by weight loss of the slugs is normal (about 0.001 inch/month) for the rather corrosive conditions used. No effect of pile radiation on corrosion rate was observed. The corrosion rate was slightly less at 92°C than at 77°C. A possible empirical relationship between Al<sup>3+</sup> activity in the water and corrosion rate is mentioned. (auth)—NSA. 16219

#### 8.4.5, 6.3.17

**A Fused Salt-Fluoride Volatility Process for Recovery and Decontamination of Uranium.** G. I. Cathers and M. R. Bennett. Oak Ridge National Lab. U. S. Atomic Energy Commission Pubn., ORNL-1885 (Del.), October 10, 1955 (Declassified with Deletions Feb. 28, 1957), 24 pp. Available from Office of Technical Services, Washington, D. C.

A preliminary chemical flowsheet is presented of a fluoride volatility process for recovering and decontaminating uranium from heterogeneous reactor fuels after dissolution in a fused salt. In laboratory work, a gross  $\beta$  decontamination factor of  $>10^4$  was obtained in the fluorination of a uranium tetrafluoride-sodium fluoride-zirconium fluoride melt by passing the product uranium hexafluoride through sodium fluoride at 650°C. The solubility of uranium hexafluoride in molten sodium fluoride-zirconium fluoride was shown in kinetic studies to cause a lag in the evolution of uranium hexafluoride from the fluorinator. Corrosion of nickel in the fluorination step appeared to be 2 to 4 mils/hr during the time that uranium was present. The average corrosion rate over the process as a whole was less than 0.4 mil/hr. (auth)—NSA. 16147

#### 8.4.5

**The Fuel System Uranium Dioxide-Phosphoric Acid-Water and Los Alamos Power Reactor Experiment II.** B. J. Thamer. Los Alamos Scientific Lab. U. S. Atomic Energy Commission Pubn., A/CONF.15/P/925, 9 pp. Prepared for the Second U. N. International Conference on the Peaceful Uses of Atomic Energy, 1958. Available from Office of Technical Services, Washington, D. C.

Dilute aqueous reactor fuels have the disadvantage of high vapor pressures at the temperatures desired for power production. The solubility, radiation stability, corrosion, vapor pressure and thermal expansion of such solutions and the reactor based on one such fuel are discussed.—NSA. 16844



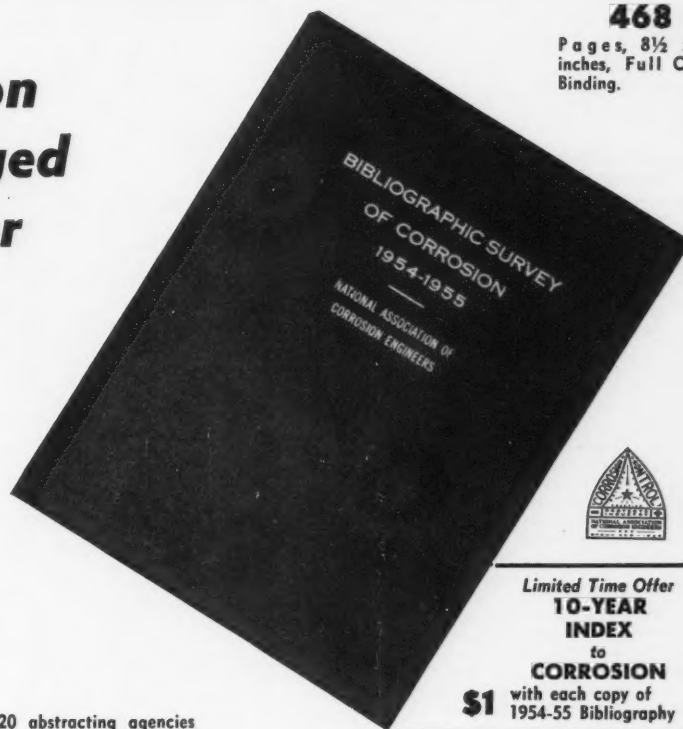
# NEW! 1954-55 BIBLIOGRAPHIC SURVEY of CORROSION

## 4287 Abstracts on Corrosion Arranged By Subject Matter

Cross-  
Indexed

•  
Alphabetical  
Subject Index

•  
Author Index



**468**

Pages, 8½ x 11  
inches, Full Cloth  
Binding.



Limited Time Offer  
**10-YEAR  
INDEX**  
to  
**CORROSION**

**\$1** with each copy of  
1954-55 Bibliography

Carefully edited and checked abstracts from some 20 abstracting agencies covering the world's literature on corrosion arranged according to the NACE Abstract Filing System. This volume includes 1945-53 abstracts not received in time to include in earlier bibliographies and brings to more than 20,000 the abstracts published in NACE surveys. A total of 4781 authors are indexed.

### Buy More Than One Volume and Save 10%

1952-53 volume, containing 3344  
abstracts, NACE members ..... \$10  
(Non-members, \$12.50)

•  
1950-51 volume, containing 4454  
abstracts, NACE members ..... \$10  
(Non-members \$12.50)

•  
1948-1949 volume, containing 3512  
abstracts, NACE members ..... \$10  
(Non-members \$12.50)

### NACE MEMBERS

**\$15<sup>00</sup>**

Non-Members . . . \$20

• Foreign remittances should be by international postal or express money order or bank draft negotiable in the U. S. for an equivalent amount of U. S. funds.

• In addition to the prices shown there is a charge of \$.60 per package for sending volumes by registered book post to addresses outside the United States, Canada and Mexico.

Send Orders and Remittances to

### Buy More Than One Volume and Save 10%

•  
1946-1947 volume, containing 3362  
abstracts, NACE members ..... \$ 7  
(Non-members \$9)

•  
1945 volume, containing 1086  
abstracts, NACE members ..... \$ 4  
(Non-members \$5)

## NATIONAL ASSOCIATION of CORROSION ENGINEERS

1061 M & M Bldg.

T. J. HULL, Executive Secretary

Houston 2, Texas

## 8.4.5, 6.6.6, 3.5.9, 3.8.4

**Some Corrosion Considerations of High-Temperature Gas-Cooled Reactors.** S. J. Yosim, R. L. McKisson, A. M. Saul and D. E. McKenzie. Atomic International Div., North American Aviation Inc. U. S. Atomic Energy Commission Pubn., A/CONF.15/P/1077, 11 pp. Prepared for the Second U. N. International Conference on the Peaceful Uses of Atomic Energy, 1958. Available from Office of Technical Service, Washington, D. C.

The basic chemical principles by which the corrosion properties and thus the temperature limitations of refractory materials may be evaluated are described. High-temperature corrosion by direct vaporization and the reaction of a gaseous component with the solid to form a gaseous product are considered.—NSA. 16862

## 8.5 Group 5

## 8.5.3

**Sulphite Pulping Operating Manual.** Tappi, 40, No. 4, 14A, 16A, 18A, 22A, 24A, 26A, 28A, 30A, 32A, 34A, 36A, 40A, 42A, 44A, 46A, 48A, 50A, 52A, 54A, 58A, 60A, 62A, 64A, 66A, 68A, 70A, 72A (1957) April.

Manual outlines major steps and equipment in making sulfite pulp and explains reasons why basic operations are carried out. Cutting edges of knives of wood shippers are made of high grade hardened steel and face plates are chromium plated steel. Sulfur burner consists of a steel or cast-iron cylinder. Spray type gas cooler consists of 1 primary and 1 secondary tower. Primary tower consists of a steel shell lined with a sheet of lead and acid-resisting tile and secondary tower is of stainless steel. Corrosion by acidic liquids and gases in digester requires that structural steel and auxiliary piping and equipment be kept well painted. All piping and fittings that come into direct contact with acid at higher temperatures must be of acid-resisting bronze or chromium-nickel steel. Large pressure vessels are usually made of structural steel but are lined with well-cemented acid-resisting ceramic tile or brick to keep shell itself from actual contact with acid contents. Blowpit is the receptacle for receiving digester charge when cook is complete and is usually made of stainless steel plate. Strainer plates may be wood, tile or stainless steel. Bronze or stainless steel plates are attached to the blowpit wall opposite blow-pipe and protect pit wall from rapid destruction by digester discharge during blow. Screen plates of screen room may be of bronze, bronze chromium-plated or stainless steel. Separators are of stainless steel, bronze or steel lined with a protective coating. A bronze or stainless steel screen of fine mesh covers open framework or cylinder mold, permitting water but not fiber to pass into interior of cylinder. Suction mold of Kamyr machine consists of a cast iron cylinder with a perforated plate cast integrally with suction chambers. Vat body is made of steel plate and lined with either stainless steel plate or copper.—INCO. 16417

## 8.5.3, 4.3.2, 6.2.5

**Sulphite Pulp Washing Practices and Trends.** W. H. Pitkin and H. L. Crosby. Paper before TAPPI, 42nd Annual

Mtg., New York, Feb. 18-21, 1957. Tappi, 40, No. 11, 204A-206A (1957) Nov.

Description of techniques used in sulfite pulp washing. Acid-sulfite liquors are extremely corrosive and for adequate protection choice of materials of construction lies between stainless steel and acid-proof tile. Type 316 stainless and 18.5 chromium, 13.0-13.5 nickel, 2.75 molybdenum and 0.03 carbon stainless were found most satisfactory. Serious corrosion difficulties might arise if chromium content were to drop below 17%. Should molybdenum figure fall below 2.5%, corrosion might also be severe, particularly if stray chlorides were present in liquor. Vats and large tanks for washing system may be tile lined and of concrete or steel. Stainless steel vats or tanks may also be used, although they are considerably more expensive.—INCO. 16243

## 8.5.3, 4.3.3

**Bleaching at the East Texas Pulp and Paper Company.** W. Robinson and J. B. Beck. Paper before TAPPI, 10th Alkaline Pulping Conf., New Orleans, November 15, 1956. TAPPI, 40, No. 9, 211A-215A (1957) Sept.

Description of 5-stage bleaching process and corrosion problems encountered. In chlorination stage, rubber lining of stock line and on agitators failed; replacement agitators were Type 317. Iron piping carrying sodium hypochlorite corroded and was replaced with saran-lined steel piping. Hastelloy C is used as lining for vertical mixer and piping in chlorine dioxide stage. Lines from chlorine dioxide seal tank to bottom of chlorine dioxide tower were of Type 317 ELC and failed within first year; they are being replaced by 317 ELC fully annealed pipe and saran-lined steel pipe. Type 317 ELC stock line from chlorine dioxide tower to washer failed within first year; it is being replaced by 317 ELC for want of better material for this spot. Various types of materials are under test to replace Type 317 ELC acid sewer line that failed. Flow charts, table of materials of construction.—INCO. 16297

## 8.5.3, 7.6.6, 6.2.3, 6.2.5

**Operating Experiences in a Neutral Sulphite Semichemical Pulp Mill.** R. W. Doe. Paper before Superintendents' Assoc., Fall Mtg., Poland Spring, Maine, 1957. Paper Trade J., 141, No. 47, 35-37 (1957) Nov. 25.

Major operating difficulties are outlined and their solutions described. Among these were barking, woodhandling maintenance, digester corrosion and refiner maintenance. First rotary digester installed was fabricated of 316 stainless and after 5 years there is no sign of corrosion. Mild steel digesters corroded badly but problem was solved by spray metallizing interiors with stainless steel. In refining process original mild steel equipment was replaced with 304 stainless.—INCO. 16155

## 8.8 Group 8

## 8.8.5

**Experiences in the Production and Processing of Small Sections Cast by the Continuous Casting Process.** (In German.) F. Leitner and F. Schmidt. Stahl u. Eisen, 78, No. 15, 1028-1032 (1958) July 24.

Covers economic conditions determin-

ing adoption of continuous casting plant, design features, description of casting process, experience gained in casting different bar sections and indication of conditions required to produce sound castings. Examples for hot-working of continuously-cast products are discussed and advantages of process are enumerated. Cross-sections of various steel castings are shown.—INCO. 16805

## 8.8.5

**Shell Molding for Steel Castings.** R. G. Powell and H. F. Taylor. Massachusetts Inst. of Technology. Trans. Am. Foundrymen's Soc., 66, 403-408 (1958); Modern Castings, 34, No. 2, 65-70 (1958) August.

Surface defects generally occurring on low-carbon and low-alloy steel castings in shell molds can be eliminated by use of chill-type shell molds. Such molds can be made with forsterite or sheep blends of granulated limestone and silica sand. Chilling effect, in respective cases, depends on high conductivity of forsterite, and on endothermic dissociation of limestone plus endothermic reaction of carbon dioxide with carbon from resin binder. Best results are obtained when these materials are used in composite shell molds. Molds should have thin facing of fine silica sand and be made by double investment process.—INCO. 16888

## 8.8.5, 6.2.5

**Powder Metallurgy of 18-8 Stainless Steel.** M. Sugiyama and H. Suzuki. Paper before Japan Inst. Met., April, 1957. J. Japan Inst. Met., 22, No. 2, 67-70 (1958) Feb.

Powdered stainless steel prepared by the intergranular corrosion method showed a better quality than that prepared by the atomizing method in stamping and sintering characteristics. Stainless steel products having the specific gravity over 6.5 g/cc were obtained from the powder prepared by the intergranular corrosion method, by stamping under a pressure of 40 tsi and by subsequent sintering at 1200 C for 1 hour. The properties of a sintered stainless steel were improved as it was sintered at higher temperatures. When a sintered stainless steel was cold worked about 40% and reheated in the furnace, the specific gravity was increased nearly to the theoretical value of a solid stainless steel.—INCO. 16895

## 8.8.5

**Some Factors Affecting the Toughness of Mild Steel Castings.** H. H. Fairfield and J. A. Ortiz. Los Angeles Steel Castings Co. Trans. Am. Foundrymen's Soc., 66, 344-348 (1958); Modern Castings, 34, No. 1, 70-74 (1958) July.

Influence of sulfur, carbon and hydrogen on steel ductility is discussed, as well as effects of various steelmaking operations during melting. Reduction of area is used as measure of toughness. All reduction of area values quoted are from separately cast test bars of electric arc furnace mild steel, normalized from 1650 F and drawn at 1250 F. Over 0.030 sulfur lowers ductility. Carbon content over 0.33 results in lower toughness than is obtained with 0.20-0.30 carbon steel. Each ppm of hydrogen may lower reduction of area by 10%. Boiling bath improves melt quality. Amount of ferrous oxide in slag before tapping has effect on reduction of area. Metal in furnace should always contain ferrous oxide as assurance against hydrogen pickup. Minimum tapping temperature of 2950 F is recommended. Tables, graphs, photomicrographs.—INCO. 16879

## 8.8.5, 6.2.2, 3.7.2

**Dross Defects in Nodular Iron Castings.** A. G. Fuller. British Cast Iron Res. Assoc., Res. Rept. No. 486. B.C.I.R.A. J. Research and Development, 7, No. 6, 368-285 (1958) June.

Dross defects, which are important problem in manufacture of magnesium-containing cast irons, were studied. Observations of nature of defect led to conclusion that it consists of segregation of mixture of magnesium sulfide and oxide, aluminum oxide, together with oxides of cadmium, iron, nickel, manganese and silicon. Ladle additions of tellurium in conjunction with ladle additions of cerium have very potent effect in reducing incidence of dross defects. On long-term basis, careful control of magnesium alloy addition and aluminum content of iron is necessary if dross defects are to be minimized. Other factors that influence incidence of dross defects include coal dust and moisture content of greensand molds, type of molding material used, pouring temperature and gating system. Experiment was carried out in which nickel content was increased by ladle additions of nickel shot prior to addition of nickel-magnesium alloy; resulting nickel content ranged 0.85-2.93. Nickel content of iron was not found to affect occurrence of dross defects. Tables, photomicrographs, graphs.—INCO. 16813

## 8.8.5, 6.2.2, 3.7.4

**Foundry Applications of the Calcium Carbide Injection Process.** W. R. Lysobey and A. E. Tull. Air Reduction Sales Co. Trans. Am. Foundrymen's Soc., 66, 327-335 (1958); Modern Castings, 34, No. 1, 53-61 (1958) July.

Discussion is confined to applications of calcium carbide injection process to gray iron containing flake graphite. Injection equipment, applications and results are described. Relationship of chill to microstructure is considered. Injection of calcium carbide in cast iron reduces chill formation and promotes formation of Type A graphite in pearlitic matrix. Extent of calcium carbide injection treatment required to produce optimum physical properties and microstructure depends upon iron composition and solidification rate. Tables summarize mechanical properties of as-melted vs injection treated iron from both cupola and induction furnace. Photomicrographs.—INCO. 16952

## 8.8.5, 6.2.2

**"Flocast" Method of Continuously Casting Iron Bar.** H. E. Morris. Foundry Trade J., 105, No. 2177, 5-13 (1958) July 3.

First published account of Flocast process for continuously casting iron bar. Set-up for pulling bar consists of: small cupolette for melting, pre-heat furnace to maintain metal temperature, die in which bar is formed, pulling mechanism, cut-off and bar-removal mechanism and electronic timing panel. Routine production run is described. Problems of flush through and hot-spotting, and manner in which these were overcome, are considered. Structure of cast bar, influence of chemical composition (phosphorus, manganese, total carbon, silicon), and hardness of bar, are covered. Elevated (up to 500 C) temperature tensile test results are presented for both standard and H.2 bar (1.5-1.8 nickel and 0.5 chromium).—INCO. 16934

## 8.8.3, 1.2.2

**Efficient Drag-Out Recovery in Barrel Nickel Plating.** R. J. Maling. Electro-

plating and Metal Finishing, 11, No. 6, 184-189, 206 (1958) June.

Describes investigation into very considerable drag-out loss from a 10 barrel plating unit. Calculations for counterflow rinse systems and on use of 1st rinse tank concentrate as drag-out led to development of continuous automatic system for maintaining bath concentration, which resulted in saving of £5,000 a year with improvement in deposit quality at capital cost for equipment of £3,000. System incorporates a 3-stage counterflow rinse system for line of 10 barrels and requires careful use of simple flow controls. Drag-out is related to "inefficiency" of solution, that is, difference between anode and cathode efficiencies, while control of temperature, pH and exhaust suction (evaporation

from main plating tank) are also important. Calculations involved are presented.—INCO. 16957

## 8.8.5

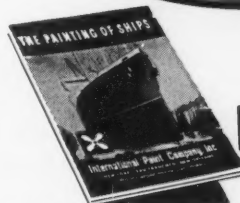
**Vacuum Casting of Steel.** J. N. Hornak and M. A. Orehoski. U. S. Steel Corp. J. Metals, 10, No. 7, 471-475 (1958) July.

A vacuum-casting process was developed which successfully reduces hydrogen concentration in steels for large forging sections to a level at which the steel is insensitive to flaking. Also, final hydrogen content of steel is at a level at which tensile ductility for aged and unaged specimens is approximately the same. Pressures at which process is conducted, however, require that special detailed attention be given to prepara-



Send for a complimentary copy of our recently revised booklet "The Painting of Ships." It is an outline of the latest approved practices in all marine maintenance.

**INTERNATIONAL PAINTS ARE  
UNIFORM . . . THE SAME HIGH  
QUALITY EVERYTIME YOU USE THEM**



Send for a complimentary copy of our recently revised booklet "The Painting of Ships." It is an outline of the latest approved practices in all marine maintenance.

INTERNATIONAL PAINTS	
Gulf Stocks at:	
SAN ANTONIO MACHINE & SUPPLY CO.	
Harlingen, Texas	Phone: GARfield 3-5330
SAN ANTONIO MACHINE & SUPPLY CO.	
Corpus Christi, Texas	Phone: 2-6991
TEXAS MARINE & INDUSTRIAL SUPPLY CO.	
Houston, Texas	Phone: WALnut 3-9771
TEXAS MARINE & INDUSTRIAL SUPPLY CO.	
Galveston, Texas	Phone: Southfield 3-2406
MARINE & PETROLEUM SUPPLY CO.	
Orange, Texas	Phone: 9-4323—8-4324
RIO FUEL & SUPPLY CO., INC.	
Morgan City, La.	Phone: 5033-3811
ROSS-WADICK SUPPLY COMPANY	
Harvey, La.	Phone: Fillmore 1-3433
VOORHIES SUPPLY COMPANY	
New Iberia, La.	Phone: EM 4-2431
MOBILE SHIP CHANDLERY CO.	
Mobile, Ala.	Phone: HEmlock 2-8583
BENT LOWE SUPPLY CO.	
Tampa, Florida	Phone: 2-4278

**International Paint Company, Inc.**

Offices:

New York 6, N. Y., 21 West St., Phone: WHitehall 3-1188  
New Orleans 15, La., 628 Pleasant St., Phone: TWinbrook 1-4435  
So. San Francisco, Cal., So. Linden Ave., Phone: Plaza 6-1440



# INDEX TO ADVERTISERS

Vol. 15

August, 1959

No. 8

	Page		Page
Amchem Products, Inc.	106	Kerr Chemicals, Inc.	103
Amercoat Corporation	Inside Front Cover	Koppers Company, Inc.	
Bart Manufacturing Corporation	119	Tar Products Division	102
Bridgeport Brass Company	77	Mayes Brothers, Inc.	113
Burndy Corporation	9	Minnesota Mining & Manufacturing Co.	
Byers, A. M. Company		Pipe Protection Products	10
PVC Pipe	97	National Association of Corrosion Engineers	109, 110, 112, 114, 116, 118, 120, 125
Wrought Iron	7	National Carbon Company	
Calgon Company, Division of		Division of Union Carbide Corp.	85
Hagan Chemicals and Controls, Inc.	92	Pittsburgh Coke and Chemical Co.	Back Cover
Carbolene Company	4	Polyken Products, Dept. of	
Cathodic Protection Service	11	The Kendall Company	70, 71
Corrosion Engineering Directory	121	Positions Wanted and Available	91
Corrosion Rectifying Company	100	Prufcoat Laboratories, Inc.	83
Corrosion Services, Inc.	115	Royston Laboratories, Inc.	79
Cosasco Division		Seamless Rubber Company, The	
Perfect Circle Corporation	5	Safe-T-Clad Division	94
DeVilbiss Co., The	68, 69	Smith, Nowery J.	108
Dowell	1	Solvay Process Division	
Duriron Company, The	Inside Back Cover	Allied Chemical Corporation	101
Federated Metals Division		Standard Magnesium Corporation	123
American Smelting & Refining Co.	75	Standard Pipeprotection, Inc.	98
Good-All Electric Manufacturing Co.	117	Tapecoat Co., The	89
Harco Corporation, The	80	Tube-Kote, Inc.	81
Humble Oil and Refining Company	66	Universal Oil Products Company	73
International Nickel Co., Inc.	104	Wholesale Coke Company	113
International Paint Company, Inc.	127		

tion of equipment and the actual vacuum casting of the steel. With adequate attention, little or no difficulty should be experienced. Tables, graphs.—INCO. 16812

## 8.8.5

**Slip Casting of Metals, Ceramics and Cermets.** P. E. Rempes, B. C. Weber and M. A. Schwartz, Paper before Am. Ceram. Soc., 59th Ann. Mtg., Dallas, May 8, 1957. Bull. Am. Ceram. Soc., 37, No. 7, 334-339 (1958) July 15.

Principles and problems in slip casting non-plastic powders are discussed and analyzed. Techniques are presented for slip casting variety of materials, including metals (titanium, chromium, molybdenum), oxides, carbides, borides, fluorides, silicides, Type 302 stainless steel and cermets such as Kentanium K184B (titanium carbide plus nickel). New "film technique" which overcomes mold release difficulties is described.—INCO. 16846

## 8.8.5, 6.3.10

**The Roll Compacting of Pure Nickel Strip from Powder.** J. A. Lund, J. Metals, 10, No. 11, 731-734 (1958) Nov.

Nickel strip having excellent mechanical properties has been prepared by direct roll-compacting of pure nickel powders produced by Sherritt Gordon Mines Ltd. followed by sintering and re-rolling of sintered compact. Effects of metal powder particle size, roll gap and roll speed on density and coherency of as-compacted strip have been studied. Influence on strip properties of sintering time and temperature, and of varying amounts of cold re-rolling were

also investigated. Sintering treatments of 15-30 minutes at temperatures of 2250-1900 F were followed by total cold reductions (in thickness of sintered strip) of up to 75%, with intermediate and final annealing treatments of 25 minutes at 1600 F. Density, tensile strength and percent elongation of strip which could be produced in this manner were similar to those for cast, rolled and annealed pure nickel. Tables, graphs, photomicrographs, equipment diagrams.—INCO. 16949

## 8.8.3

**The Protection of Threaded Parts by Electroplating.** E. A. Ollard, Corrosion Prevention and Control, 4, No. 8, 41-44 (1957) August.

Discusses the plating of steel and brass screws with zinc, cadmium, tin, nickel plus chromium, brass and copper. Cadmium is most expensive metal in use for protection of steel screws. Zinc is somewhat cheaper and quite satisfactory for many purposes; its resistance to industrial atmosphere is often better than cadmium. Nickel is more generally used for protection of screws, etc., for internal assemblies of meters, instruments and the like. Nickel plating must be continuous and free from porosity since exposed steel will corrode in preference to nickel (contrary to protection given by zinc and cadmium). Barrel plating method and techniques used to control coating thickness are discussed. Nickel plated steel and brass screws are tested by jet test in which coating is dissolved off with special complex agent and loss in weight is estimated. Line of horizon-

tal immersed barrels for nickel plating at Atlas Plating Works is shown. 2 illustrations.—INCO. 16261

## 8.8.3, 5.3.4

**Recent Developments in Copper Plating.** D. E. Weimer, Paper before Inst. Met. Finishing, Bristol, October 15, 1957. Bull. Inst. Met. Finishing, 7, No. 3, 13-24 (1957) Autumn; Trans. Inst. Met. Finishing, 35, 13-24 (1958).

Application and deposit characteristics of copper which are required in decorative electroplating are discussed. Developments are divided into 2 groups: improvements in established electrolytes (basic cyanide copper and acid sulfate copper) and introduction of new solutions (pyro-phosphate copper). There is little evidence to show that inherent problems in cyanide and acid sulfate electrodeposition have been overcome in spite of addition agents designed to improve brightness and levelling action. Account is given of pyrophosphate solution now in commercial application. World shortage of nickel has accentuated need for easily buffed undercoat for nickel. From experience in automobile industry and domestic appliance industries, it appears that service of copper-nickel-chromium system compares favorably with ordinary nickel-chromium plating.—INCO. 16409

## 8.8.3, 6.3.17

**Electroplating.** Final Report on P.A. No. 154-ML-52-2. Ralph Wehrmann. Chicago Univ. U. S. Atomic Energy Commission Pubn., CT-2443, Dec. 1, 1944 (Declassified Feb. 23, 1957), 26 pp. Available from Office of Technical Services, Washington, D. C.

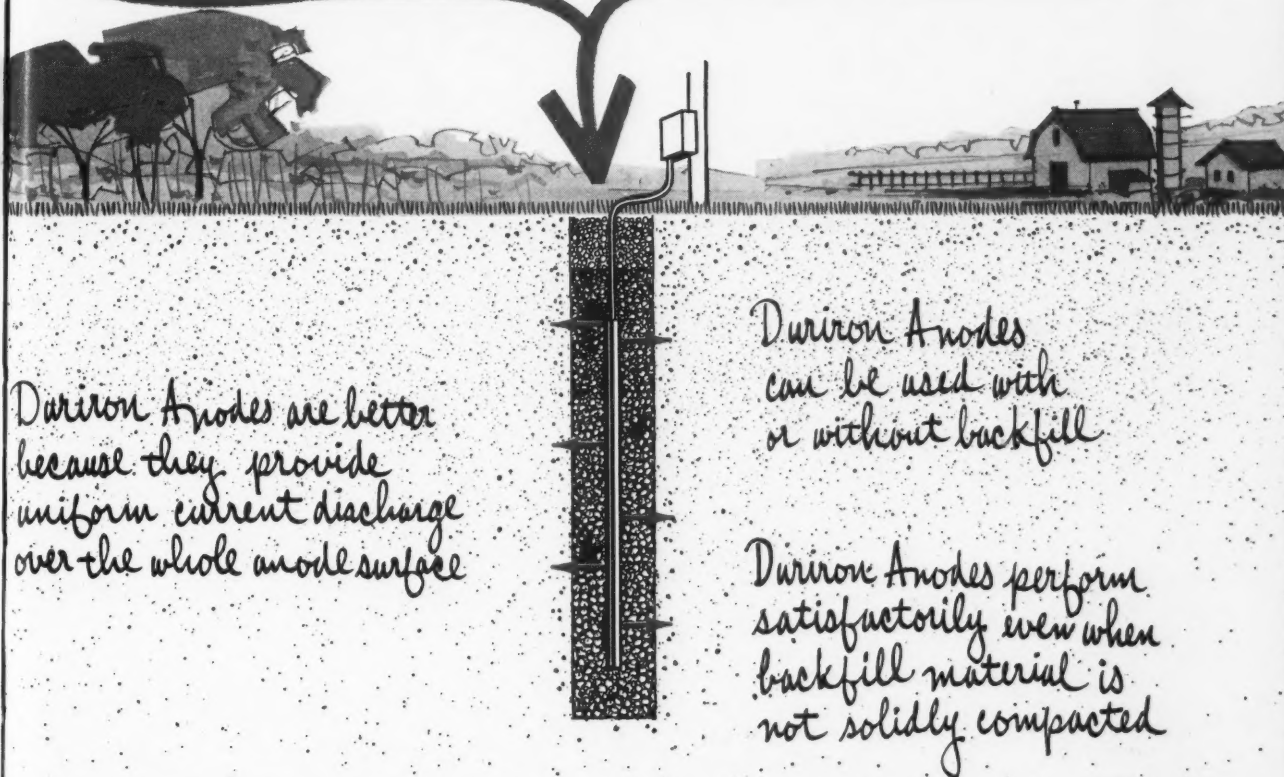
A procedure for electroplating uranium was developed which involves anodic treatment of uranium in a concentrated solution of trichloroacetic acid prior to plating. Uniform and rapid attack on uranium, small metal loss and good plate adherence are advantages of the method. The corrosion resistance of diffused (high temperature) nickel and nickel-molybdenum plates appears to be 10 to 100 times better than unalloyed uranium. (auth)—NSA. 16369

## 8.8.3, 5.3.4

**An Investigation of the Mechanism of Levelling in Electrodeposition.** S. A. Watson and J. Edwards, Paper before Inst. Metal Finishing, Annual Conf., April 9-13, 1957. Electroplating and Metal Finishing, 10, No. 5, 136-137; disc. 137-138 (1957) May.

Experiments were carried out using copper electroformed L.P. record masters. Using standard plating procedure, 0.27 mil deposits of nickel were plated and backed up with an acid copper deposit. Cathode efficiency was determined. Cathode potential for nickel solutions with different addition agents and at various densities was measured. Levelling power was determined microscopically from difference between groove depth before and after plating (difference between average thickness in recesses minus thickness on peaks, divided by average thickness). On diamond ruled surfaces, several nickel deposits were separated by copper; levelling action was measured by reciprocal of number of nickel coats needed to fill grooves completely. By etching cross-sections of deposits, distribution of incorporated matter was determined. Control of levelling agent is considered. P. Hersch (Mond) contributed to discussion.—INCO. 16379

# WHEN BACKFILLING IS NOT PERFECT, due to poor compacting or the inclusion of clods, rocks, or other obstructions, **DURIRON ANODES** **OUT-PERFORM ALL OTHERS**



*Duriron Anodes are better  
because they provide  
uniform current discharge  
over the whole anode surface*

*Duriron Anodes  
can be used with  
or without backfill*

*Duriron Anodes perform  
satisfactorily even when  
backfill material is  
not solidly compacted*

Duriron anodes have a dense, homogeneous, metallic structure. They provide uniform current discharge with low consumption rates. Over five years of field and laboratory test data have proved that for the protection of underground structures, in every case Duriron will perform just as well as graphite, and in the really tough cases, Duriron performs better.

For complete details of Duriron Anodes for use in ground beds, fresh water, salt water and duct applications, ask for Durco Bulletin DA/6.

**THE DURIRON COMPANY, INC., DAYTON, OHIO**

BRANCH OFFICES: Baltimore, Boston, Buffalo, Chicago, Cleveland, Dayton, Detroit, Houston, Knoxville, Los Angeles, New York, Pensacola, Philadelphia, Pittsburgh, and St. Louis

From the desk of J.L. MARTIN

Don -

Have you seen these latest figures on cathodic protection costs on pipelines? They're based on one mile of 24" pipe after several years of service -

<u>Coating</u>	<u>Resistance</u> (ohms/sq. ft.)	<u>Installation</u>	<u>Annual</u> <u>Upkeep</u>
Coal Tar Enamel	300,000+	\$ 112.	\$ 33.
"Economy" Enamel	10,000-	\$ 2,740.	\$ 520.

I'm convinced we can hardly afford to use anything but coal tar for our new line.

Lets' specify Pitt Chem Modified Coal Tar Enamel. I understand they make top quality products - and back them up with excellent technical field service.

*Jim*

- ★ PITT CHEM® Coal Tar Pipeline Enamels
- ★ PITT CHEM "Tarmastic"® Coal Tar Coatings
- ★ PITT CHEM "Tarset"® Coal Tar-Epoxy Resin Coatings
- ★ PITT CHEM "Insul-Mastic"® Gilsonite-Asphalt Coatings

